# ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY W. H. MAW AND ALEX. RICHARDSON.

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1922.

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Engineering Library


# ENGINEERING:

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VOL. CXIII.—No. 2923.] *LONDON: FRIDAY, JANUARY 6, 1922.* [Registered at the General Post Office as a Newspaper.] [Price ... 1s. By Foreign Post 1s. 4d.



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See page 17, Dec. 30. 9108

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See Advertisement page 77.

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See Advertisement, page 28. 9091

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GOLD MEDAL—Exhibitions Exhibition—Awarded.
**Duckham's Patent Suspended**
WEIGHING MACHINES.—EAST FERRY ROAD ENGINEERING WORKS COMPANY, Ltd., London, E.—Hydraulic Cranes, Grain Elevators, &c. See Illus. Advt. last week, page 15. 9704

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Builders of RAILWAY CARRIAGES, WAGONS ELECTRIC CARS, and every other description of RAILWAY and TRAMWAY ROLLING STOCK, Makers of WHEELS and AXLES, RAILWAY PLANT, FORGINGS, SMITHS' WORK, IRON and BRASS CASTINGS, PRESSED STEEL WORK of all KINDS.
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See Advertisements page 80, Dec. 30. 9003

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See half-page Advertisement page 73, Dec. 30.

See Advt. Page 66 Dec. 30.
**Steam Hammers**
**Power Hammers**
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## The Manchester Steam Users' ASSOCIATION.

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Please address all communications for them so.

9741

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### TENDERS.

## Tenders are Invited by

the GOVERNMENT of NEW SOUTH WALES for the CONSTRUCTION of the SUPERSTRUCTURE and SUBSTRUCTURE of a CANTILEVER BRIDGE ACROSS SYDNEY HARBOUR from DAWES POINT to MILSON'S POINT, embracing a main span of 1600 ft. in the clear, centre to centre of main piers, or 2000 ft. centre to centre of anchor piers. The total length of bridge included in tender is 3816 ft., centre to centre of abutments. The deck of the bridge is to include four lines of railway, and a roadway 36 ft. wide, between main trusses; and cantilevered outside the main trusses on the western side, a footway 15 ft. wide, and on the eastern side a motor roadway 18 ft. wide. Copies of specification, including plans, general conditions, and schedule of quantities may be obtained on application to the undersigned.

To give any information required by Tenderers, Mr. J. J. C. Bradfield, Chief Engineer, will be in London during June and July, 1922, address care of the undersigned.

Tenders in accordance with the specification must reach the Under Secretary for Public Works, Sydney, not later than 31st October, 1922.

AGENT-GENERAL FOR NEW SOUTH WALES.

Australia House, Strand, London, W.C. 2.
December, 1921. T 34

### CONTRACTS.

#### CORPORATION OF DUBLIN.

The Corporation of Dublin is prepared to receive

## Tenders for the Cast-Iron

PIPES, VALVES, CASTINGS, and other necessary FITTINGS required for the Valve Tower of the New Reservoir at Roundwood, Co. Wicklow.

The Drawings and Specifications may be seen at the Borough Surveyor's Office, 28, Castle Street, Dublin, between the hours of Eleven a.m. and Four p.m., on and after the 31st of December, 1921, and copies may be had on payment of a sum of 1l., which will be refunded on the receipt of a *bona fide* Tender.

The Corporation does not bind itself to accept the lowest or any Tender.

Tenderers must submit the names of substantial securities. Inquiries as to the said sureties' financial position will be made, and if the results of such inquiries be unsatisfactory, the Tender or Tenders submitted with such sureties will not be further considered.

No Tender will be considered unless it is furnished on the provided Tender Form.

Tenders will be considered only from firms accustomed to supplying materials of the class required, and capable of themselves manufacturing all the pipes, valves, castings and all the other fittings required.

Sealed Tenders (accompanied by Drawings and Specifications) endorsed: "Tender for Pipes, Valves, etc., for Valve Tower, New Reservoir, Roundwood, Co. Wicklow," should be addressed to the CHAIRMAN, Waterworks Committee, 18, Parnell Square, Dublin, and should be delivered not later than One p.m., on Monday, the 16th January, 1922.

By Order,
JOHN J. MURPHY,
Town Clerk. T 11

THE BARNOLDSWICK URBAN DISTRICT COUNCIL invite

## Tenders for the Supply,

DELIVERY and ERECTION of a STEAM TRAVELLING CRANE, with 40 ft. jib, to handle loads up to two tons.

Also include in Tender for the Supply, Delivery, and Fixing of 80 ft. of RAILS, to be laid on the ground complete with Sleepers, and the whole to be left ready for use. Date to be stated.

Tender due 18th January, 1922.

J. W. THOMPSON,
Engineer & Manager. T 24

#### MANCHESTER CORPORATION WATERWORKS.

THIRLMERE AQUEDUCT—4TH PIPE LINE.

The Waterworks Committee invite

## Tenders for the Laying and

JOINTING of 54 inch WELDED STEEL and other PIPES, the Fixing of Valves and Ironwork, the Construction of Subways under Railways, etc., and other work connected with the FOURTH PIPE LINE from THIRLMERE to MANCHESTER, as follows:—

CONTRACT "A." Ambleside to South of Kendal (about 8½ miles).
CONTRACT "B." Kirkby Lonsdale to Lancaster (about 8½ miles).
CONTRACT "C." South of Lancaster to River Ribble (about 4½ miles).
CONTRACT "D." River Ribble to Horwich (about 6½ miles).

Printed Specifications, schedules of Quantities, and forms of Tender, may be obtained on application to the Secretary, Waterworks Offices, Town Hall, Manchester, on receipt of a deposit of Five Guineas for each contract, which will only be returned to the tenderer provided that he shall have sent in a *bona fide* Tender, and shall have returned the documents lent to him. Plans and Drawings may be inspected on application to the Waterworks Engineer. Only a limited number of the drawings being available, these, excluding ordnance maps, will be lent to persons tendering in priority of application, on payment of the sum of Three Guineas, which sum will not be returned.

Sealed Tenders, endorsed as directed in the schedules, must be delivered at the Waterworks Offices, Town Hall, Manchester, not later than the 9th of February, 1922.

By Order,
THOMAS HUDSON,
Town Clerk.
Town Hall, Manchester,
29th December, 1921. T 8

#### THE GREAT INDIAN PENINSULA RAILWAY COMPANY.

The Directors are prepared to receive

## Tenders for the Supply of

the following STORES, namely:—

Fee for Specification.

No. 8. Spare Parts of Carriages and Wagons (Buffers, Buffer Rods and Heads) £1
No. 9. Steel Work for Bridges (160 ft. spans) £1

Specifications and Forms of Tender may be obtained at this office on payment of the fee for the Specification, which payment will not be returned.

The fee should accompany any application by post. Cheques and Postal Orders should be crossed and made payable to the Great Indian Peninsula Railway Company.

Tenders must be delivered in separate envelopes, sealed and addressed to the undersigned, marked "Tender for Buffers, Buffer Rods and Heads" or as the case may be, not later than Eleven o'clock a.m., on Tuesday, the 17th January, 1922.

The Directors do not bind themselves to accept the lowest or any Tender.

R. H. WALPOLE,
Secretary.
Company's Offices,
48, Copthall Avenue, E.C. 2.
London, 4th January, 1922. T 51

#### THE BENGAL AND NORTH WESTERN RAILWAY COMPANY, LIMITED.

The Directors are prepared to receive

## Tenders for the Supply

of:—

1200 VOLUTH SPRINGS,
550 C. & W. TYRES,

as per Specification to be seen at the Company's Offices.

Tenders addressed to the undersigned, and marked "Tender for Volute Springs," or as the case may be, are to be lodged not later than noon on Monday, the 23rd day of January, 1923.

For each Specification a fee of 10s. will be charged which cannot under any circumstances be returned.

The Directors do not bind themselves to accept the lowest or any tender.

By Order of the Board,
R. A. NEWILLE,
Managing Director,
297, Gresham House,
Old Broad Street,
London, E.C. 2.
4th January, 1922. T 57

#### EAST INDIAN RAILWAY.

The East Indian Railway Company is prepared to receive

## Tenders for the Supply and

DELIVERY of—

MISCELLANEOUS TOOLS & STORES,

as per Specification to be seen at the Company's Offices.

Tenders are to be sent to the undersigned, marked "Tender for Miscellaneous Tools, etc.," not later than Eleven o'clock a.m. on Wednesday, the 25th day of January, instant.

The Company reserves to itself the right to divide the order, also to decline any tender without assigning a reason and does not bind itself to accept the lowest or any tender.

For each Specification a fee of £1 1s. is charged, which cannot under any circumstances be returned.

By Order,
G. H. LILLIE,
Secretary.
Nicholas Lane, London, E.C. 4.
4th January, 1922. T 30

THE HIGH COMMISSIONER FOR INDIA is prepared to receive

## Tenders for the Supply

of:—

BUFFERS,
ENGINE TURNTABLES.

Forms of Tender may be obtained from the Director-General, India Store Department, Belvedere Road, Lambeth, S.E. 1, and Tenders are to be delivered at that Office not later than Two o'clock p.m. on Tuesday, the 31st January, 1922.

T. RYAN,
Director-General. T 45

### APPOINTMENTS OPEN.

#### SWINDON AND NORTH WILTS TECHNICAL INSTITUTION.

Principal:—G. H. BURKHARDT, M.A., M.Sc.

## Applications are Invited for

the POST of HEAD OF THE ENGINEERING DEPARTMENT from graduates in Engineering. Both works experience and teaching experience are essential.

Salary according to Burnham Scale with three-quarter "carry-over" as from September, 1921.

Further particulars and forms of application may be obtained from the PRINCIPAL, Technical Institution, Swindon.

W. SEATON,
Secretary. T 36

#### UNIVERSITY OF HONG KONG.

## Two Lecturers in Mechanical

Engineering are REQUIRED for the University of Hong Kong. Five years' agreement: salary £500 per annum, converted for purposes of local payment at 2s. to the dollar, free quarters or allowance of £100, half salary from date of embarkation. Candidates should be graduates in Engineering of some British University and preferably unmarried.

Applications should be submitted in covers marked "C.A.," and addressed to the SECRETARY, BOARD OF EDUCATION, Whitehall, London, S.W. 1. Scottish candidates should apply to the SECRETARY, SCOTTISH EDUCATION DEPARTMENT, Whitehall, London, S.W. 1. T 68

## Secretary-Director Required,

preferably with knowledge of Engineering, to control London Office of provincial manufacturing company owning rapidly-increasing business. Audited accounts show net profit of 56 per cent. p.a. on invested capital after payment of Directors' salaries. Investment £2000. Salary £520 p.a. plus dividends. Open to Solicitors' and Accountants' investigation.—Write, Box 1355, SELLS, 167, Fleet Street, E.C. 4. T 32

## Foundry Commercial Manager

REQUIRED by firm in the Midlands with well-equipped foundry. Applicant must have thorough knowledge of the trade and an existing connection with customers and be prepared to introduce new lines of trade and customers. Applicant with knowledge of high-class heating stove trade preferred. — Address, Offices of ENGINEERING. T 16

## Engineer Salesman Required

by Firm of mechanical and general engineers with Head Office in Scotland. Must have practical training as Engineer and subsequent experience as salesman. Connection with food manufacturers a recommendation. Full particulars of experience, when free, and salary required.—Box No. 10, BROWN'S Advertising Offices, 166, Buchanan Street, Glasgow. T 17

## Wanted, Engineer for Blast

Furnace Plant. Must be experienced with Electric Power.—Address, stating age, experience and salary required, T 37, Offices of ENGINEERING.

#### CORPORATION OF CALCUTTA.

APPOINTMENT OF EXECUTIVE ENGINEER, DRAINAGE.

## Applications are Invited for

the POST of EXECUTIVE ENGINEER, Drainage, Calcutta. The salary of the appointment inclusive of all allowances is Rs. 1300 rising to Rs. 1500 per month by annual increments of Rs. 50. The person appointed will be required to keep a motor car. The cost of a motor car will, if desired, be advanced by the Corporation and recovered in monthly instalments spread over three years.

The appointment is subject to the Provident Fund, Leave and other service rules of the Corporation and may be terminated at any time by six months' notice on either side. The Provident Fund contribution is 8½ per cent. of the monthly salary and an equivalent amount is contributed by the Corporation and the fund accumulates at compound interest. The selected candidate will be under the direction of the Chief Engineer and be required to devote his whole time to the duties of his office and will not be allowed to take up any private work. He must reside in Calcutta. He will be liable to removal during the term of his office for misconduct or neglect of, or incapacity for his duties. He will be required to submit to a medical examination before joining his appointment. The Corporation will pay his passage (first class) from London to Calcutta, but he must refund the amount so paid, if he gives notice anytime within two years from the date of taking up his appointment. He will be required to take up his appointment within two months of receiving notice of appointment and will receive half pay for the period occupied by the journey.

(a) Preference will be given to candidates who are Members or Associate Members of the Institute of Civil Engineers or Graduates in Engineering of a University, and have had experience in the design, construction and maintenance of sewerage projects for large cities including pipe and masonry sewers, Pumping Stations, sewage treatment and disposal, as well as road and general construction works.

(c) Candidates are to state their age and experience.

(d) Applications will be received in the United Kingdom up to Monday, the 30th January, 1922, by W. C. HASTON, Esq., B.S.C., M.I.C.E., 149, West George Street, Glasgow, from whom any other information concerning the conditions of service, etc., may be obtained.

B. V. RAMIAH,
Secretary to the Corporation.
Central Municipal Office,
8th December, 1921. T 15

## Required for the Service

of the GOVERNMENT OF INDIA an INSPECTOR OF CASTINGS at the Government Test House, Alipore. Candidates must be physically fit for service in India, of fair education and good moral character. Following qualifications essential:—Candidates to be between 25 and 35 years age of good address, must have served apprenticeship with a well-known firm of pipe founders, have a thorough knowledge of moulding generally and be able to write intelligent reports. Candidate who has been foreman in an up-to-date works preferred.

TERMS—Engagement for three years in first instance.

SALARY—Rs. 450 per month rising by annual increments of Rs. 25 to Rs. 550 monthly.

Further particulars and forms of application from the DIRECTOR-GENERAL, INDIA STORE DEPARTMENT, Belvedere Road, London, S.E. 1. Quote reference S.21367/1921 when applying. T 18

## Chief Assistant to Sales

Manager REQUIRED by important firm building large furnaces, and other metallurgical plant. Technical training essential, Engineering or Metallurgy. Young University man with sound practical experience prefered. — Address, stating age, training, experience and salary required, T 3, Offices of ENGINEERING.

## Assistant Engineer Required

for Estimating and Contracts Department. Public School and University man preferred. Practical training and knowledge in design of centrifugal and turbine pumps essential. Applicant should be energetic and fully experienced in pushing sales.—Apply, stating age, full experience and salary required, to W. H. ALLEN, SONS & CO., Ltd., Queen's Engineering Works, Bedford. T 38

## Two Driver Fitters Required

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ENGINEERING

## THE PROPORTIONING OF STEAM TURBINE BLADING.

By HAROLD MEDWAY MARTIN, Wh.Sc., A.C.G.I.

OWING to the incompressibility of water, the rational proportionment of the blading for a water turbine is a much simpler matter than it is in the case of a steam turbine. The latter, from the standpoint of hydraulics, corresponds to a series of water turbines arranged one below the other on the same fall, each utilising a definite fraction of the total head, but whatever be the proportion of the total head expended in the case of the water turbines, the volume of 1 lb. of water remains unaltered during the whole of its passage from the initial penstock to the final tail race of the series. With steam, matters are much less simple. Corresponding to the static head in a water turbine, we have an effective thermodynamic head which may be represented by U, and this is most conveniently expressed in thermal units per pound of steam.* The velocity of efflux from the guide blades of a water turbine is proportional to the square root of the static head expended there, and similarly in the case of a steam turbine the velocity of efflux is (with certain limitations due to "carry over") proportional to the square root of $q$, where $q$ denotes the thermodynamic head expended at that particular stage.

The analogy between the water turbine and the steam turbine ends here, however, for whilst water does not expand as its original static head is used up from turbine to turbine in a series, steam undergoes an enormous expansion; the volume being perhaps 200 times as great when the steam is discharged into the condenser as when supplied at the turbine stop valve. An additional complication is introduced by the fact that the effective thermodynamic head, under which a steam turbine operates, is a function not merely of the initial pressure and superheat, and of the condenser pressure, but also depends on the turbine efficiency, whilst in the case of a series of water turbines the available head is fixed solely by the total difference of level between the intake and tail race. So long as a steam turbine is operated with superheated or dry supersaturated steam, the determination of the effective head is relatively simple, but since wet steam does not expand through a turbine in a condition of thermal equilibrium, it is necessary to adopt empirical methods in designing the low-pressure sections of steam turbines. One such rule has been described by Mr. K. Baumann, in a paper* read before the Institution of Electrical Engineers last March. He assumes that at each stage of the expansion of wet steam, the efficiency is reduced 1 per cent. for each 1 per cent. of moisture present, the steam being assumed to expand in a condition of thermal equilibrium. This rule, which originated before the important part played by supersaturation was realised, yields results in good accord with actual experience, but the apparent inferiority of a turbine working with wet steam as compared with a turbine operated with superheated steam is attributed to a lower stage efficiency, and the total effective thermodynamic head is (on this hypothesis) actually greater than it would be were the efficiency unaltered. For the reasons developed in a "New Theory of a Steam Turbine," published in ENGINEERING, July 5, 1918, *et seq.*, we shall assume, on the other hand, that the inferiority of the turbine working with wet steam is apparent only, being due to the fact, that a considerable fraction of the thermodynamic head, with which it has been debited in the past, never becomes available, owing to the circumstance that no condensation of the steam occurs until the Wilson line is crossed, and that subsequently the steam is still not in thermal equilibrium, but expands as wet supersaturated steam. Direct experimental proof of an expansion of this kind was obtained in the original experiments† of Mr. C. T. R. Wilson, F.R.S., who found that when dust-free steam was expanded beyond the supersaturation limit, the further condensation which occurred came down on new nuclei and not on the droplets already formed. Throughout the whole of such an expansion, therefore, the specific volume of the steam is less than if the expansion had been effected in a condition of thermal equilibrium, and the thermodynamic head expended is correspondingly smaller.

The laws of expansion of supersaturated steam still require further experimental investigation, but if we take it that Mr. Baumann's rule gives us the useful work done by a turbine working with wet steam, we can deduce an empirical rule for the thermodynamic head expended in the process, on the assumption that the stage efficiency is the same as if the steam were superheated. Denoting this thermodynamic head by $U_s$, we may write $U_s = \psi u_s$ where $\psi$ is a coefficient and $u_s$ is equal to the adiabatic heat drop for an expansion in thermal equilibrium, from the saturation line to the final pressure. The "indicated work" done in the expansion will be $\eta U_s$ where $\eta$ denotes the hydraulic efficiency, and this indicated work will be practically the same as that deduced from Mr. Baumann's rule, if we write

$$\psi = 1{\cdot}1070 + 0{\cdot}0221\frac{x}{100} - \eta\left(0{\cdot}1638 + 0{\cdot}0286\frac{x}{100}\right)$$

where $x$ denotes the ratio of the initial pressure $p_s$ to the final pressure.

The formula is, of course, empirical, the coefficients being selected to give results in accord with Mr. Baumann's rule for such values of $\eta$ as are usual in practice. From theoretical considerations, however, the present writer is inclined to think that this rule gives rather too large results for the "indicated" work, when $x$ is small, and it will accordingly be assumed that

$$\psi = 1{\cdot}0352 + 0{\cdot}04\frac{x}{100} - \eta\left(0{\cdot}089 + 0{\cdot}047\frac{x}{100}\right)$$

This yields results in good agreement with Mr. Baumann's rule when $x$ is large, and with theory when the expansion is stopped at the Wilson line. For expansions effected wholly above the saturation line the thermodynamic head $U^1$ is equal to $R.u^1$, where $u^1$ denotes the adiabatic heat drop, and R the appropriate reheat factor. A diagram giving at sight reheat factors for different efficiencies and ranges of expansion was published in ENGINEERING July 5, 1918, Plate 1.

Hence, when as is usual, a turbine is supplied with superheated steam, and exhausts it in the wet condition, the total thermodynamic head U is given by the relation

$$U = U^1 + U_s = \frac{1}{\eta}\left(H_i - H_e\right)$$

where $U^1$ denotes the thermodynamic head expanded down to the saturation line and $U_s$ the head expended in the remainder of the expansion. The hydraulic efficiency is denoted by $\eta$, whilst $H_i$ denotes the total heat of the steam as supplied *ab initio*, and $H_e$ the total heat carried away by the exhaust steam.

Having thus found the effective head we can determine forthwith the general dimensions of a compound turbine to operate with a given indicated hydraulic efficiency. Thus let us define K by the equation

$$K = \Sigma\left(\frac{d}{10}\right)^2\left(\frac{R.P.M}{100}\right)^2$$

where the summation extends over moving rows of blades only, and $d$ denotes the mean diameter of a blade row in inches.

Then it is obvious that $\frac{K}{U}$ is proportional to the mean square of the blade speed, divided by the mean square of the steam speed.

If then we plot the hydraulic efficiency $\eta$ against $\frac{K}{U}$ we get an ellipse of which the equation is

$$\left(\frac{\eta}{\eta_1} + \frac{K}{U}\cdot\frac{U_1}{K_1}\right)^2 = 4\,\frac{K}{U}\cdot\frac{U_1}{K_1}$$

where $U_1$ and $K_1$ are the values of U and K

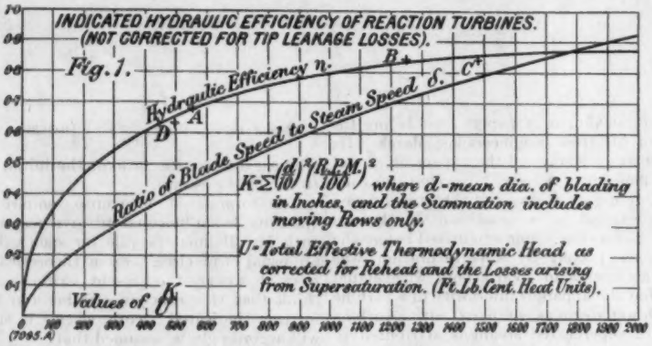
* U is, of course, not the adiabatic heat drop, but is proportional to the area of the indicator diagram (expressed in heat units), which would be obtained were the steam expanded behind a piston, heat being added to it, in the course of its expansion, just as it is in a turbine.

* *See* ENGINEERING, April 8, 1921, p. 435, *et seq.*
† Phil. Trans. 1907. Vol. clxxxix, page 307.

corresponding to the maximum efficiency possible with the type of turbine under consideration.

An efficiency ellipse of this kind for reaction turbines has been plotted in Fig. 1, annexed. From the curve it will be seen that if we know the effective thermodynamic head U we can at once determine the value of K necessary for a given hydraulic efficiency. Thus for $\eta = 0{\cdot}80$ we get from Fig. 1 $K = 1010\,U$. The curve is based on actual test results.

Really reliable and complete test figures are very difficult to obtain. Most tests are run merely with the object of passing the guarantees, and the actual figures recorded depend very much on the alertness and reliability of the station engineers. We know of one case in which two impulse turbines of the same make and designed to have the same efficiency, were tested at different power stations within a fortnight of each other, and the discrepancy between the two results was 5 per cent. Again, reaction turbine builders very seldom give in their test data the pressure below the governor valve, nor do they state whether or no the bye-pass was in action. It is thus commonly necessary to guess at the actual initial conditions. In general, ignorance of


INDICATED HYDRAULIC EFFICIENCY OF REACTION TURBINES.
(NOT CORRECTED FOR TIP LEAKAGE LOSSES).
Fig. 1.
Hydraulic Efficiency η.
Ratio of Blade Speed to Steam Speed δ.
K-Σ(d/60)²(R.P.M./100)² where d-mean dia. of blading in Inches, and the Summation includes moving Rows only.
U-Total Effective Thermodynamic Head as corrected for Reheat and the Losses arising from Supersaturation. (Ft.lb.Cent.Heat Units).
Values of K.

the unpublished factors tends to make the inquirer underestimate the real efficiency of the turbine, but some tests have been recorded in which substantially higher efficiencies are claimed than would be anticipated from the curve. The data represented by the points A and B were, however, obtained from trials in which very exceptional care was taken to secure as accurate figures as possible. The point A represents the mean result of eight runs made with a turbine tested under nearly laboratory conditions, and the writer is indebted to Mr. Eric Brown for the information from which the point A has been plotted. It is perhaps a little low as the tip clearances were larger than usual. The point B was deduced from the tests of the 25,000–30,000 kw. Interborough turbine described in the journal of the American Society of Mechanical Engineers for June, 1916. The data given are exceptionally complete, and very special care was taken to secure accuracy. The point C is less satisfactorily fixed. The tests on which it is based were remarkably consistent *inter se*, and were made independently of the builders and under very competent direction. The turbine had, however, an extraordinarily restricted steam way through the last row of blades, so that the "throw-away" loss was of the order of 8 per cent. instead of between 2 per cent. and 3 per cent. An adjustment has therefore been necessary, and the point plotted does not represent the actual test figures, but has been corrected for these abnormal exhaust losses.

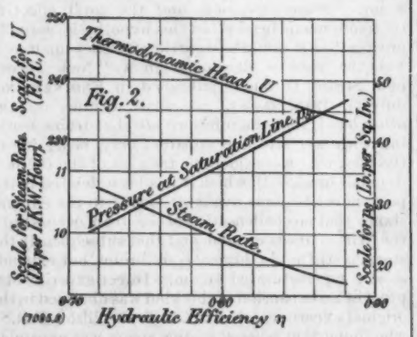
The determination of the effective thermodynamic head and the consequent deduction of K constitute, however, only a first step in the rational proportionment of turbine blading. It is necessary, in addition, to know, either implicitly or explicitly, the relation between the thermodynamic head U and the specific volume V, and as already explained, this relation is not a constant one, but is a function not merely of the initial pressure and superheat, and of the condenser pressure, but also depends on $\eta$, the hydraulic efficiency of the turbine.

In practice, what the designer has given him, amongst his primary data, is not this hydraulic efficiency but the steam rate required per kilowatt-hour at the switchboard. This he can easily reduce to the steam rate per indicated kilowatt-hour.

It is accordingly proposed to find, in the first instance, what is the hydraulic efficiency corresponding to various steam rates per indicated kilowatt-hour when, for example, the steam is supplied at a stop valve pressure of 250 lb. per square inch (gauge) and at a stop valve temperature of 300 deg. C., the designed exhaust pressure being 0·491 lb. per square inch absolute, which is equivalent to a vacuum of 29 in. of mercury.

From Callendar's tables we note that steam at a pressure of 250 lb. per square inch absolute and at a temperature of 300 deg. C. has a total heat of 728·82 foot-pound Centigrade heat units. These units we shall denote in future as F.P.C. The tables also show that if the temperature of the steam be kept constant the total heat will be diminished by 0·432 units for each 10 lb. increase in the pressure. Hence at 300 deg. C. and 250 lb. (gauge) pressure the total heat will be $728{\cdot}82 - 1{\cdot}47 \times 0{\cdot}432 = 728{\cdot}19$ F.P.C.

We may take it that at full load the loss of pressure through the valve system will be about 9 per cent. of the absolute pressure of supply, so


Thermodynamic Head. U
Scale for U (F.P.C.)
Fig. 2.
Pressure at Saturation Line.
Steam Rate.
Scale for Steam Rate (Lbs. per I.K.W. Hour)
Scale for p (Lbs. per Sq. In.)
Hydraulic Efficiency η

that $p_1$, the absolute pressure in front of the first row of guide blades will be, say, 238 lb. per square inch absolute.

There is no loss of total heat by the wire drawing of the steam through the valves, so that the total heat $H_1$ of the steam as it reaches the first row of guide blades is still 728·19 F.P.C. We can find $V_1$, the corresponding specific volume of the steam, by Callendar's rational equation, viz.:

$$V = \frac{2{\cdot}2436\,.\,(H - 464)}{p} + 0{\cdot}0123.$$

From which, in this instance, we get $V_1 = 2{\cdot}493$ cub. ft. per pound.

Reference to a steam chart shows that were the expansion adiabatic, that is to say, did it proceed with unit hydraulic efficiency, the saturation line would be crossed at a pressure of somewhere about 52 lb. per square inch, and the lower the efficiency the lower the pressure at the crossing point.

Let us determine what are the hydraulic efficiencies, when the saturation line is crossed at absolute pressures of 46 lb., 36 lb. and 26 lb. per square inch respectively.

In any expansion of superheated steam at constant hydraulic efficiency the relation between pressure and temperature is given accurately by the expression:

$$\frac{1}{p\lambda}\left(V - \frac{0{\cdot}016\,\lambda}{1{\cdot}3}\right) = \text{constant},$$

where

$$\frac{1}{\lambda} = 1 - 0{\cdot}23077\,\eta\ *$$

Some values of $\frac{1}{\lambda}$ and of $\frac{0{\cdot}016\,\lambda}{1{\cdot}3}$ are given below:

| | | | | |
|---|---|---|---|---|
| $\eta =$ | 0·6 | 0·7 | 0·8 | 1·0 |
| $\frac{1}{\lambda} =$ | 0·8615 | 0·8384 | 0·8154 | 0·7692 |
| $\frac{0{\cdot}016\,\lambda}{1{\cdot}3} =$ | 0·0143 | 0·0147 | 0·0151 | 0·016 |

Hence for such efficiencies as are usual in modern turbines we may, without material error, take $\frac{0{\cdot}016\,\lambda}{1{\cdot}3}$ as constant and equal to 0·015.

Now if $p_1$ and $V_1$ be respectively the pressure and the volume before the first row of guide blades, whilst $p_s$ and $V_s$ denote the corresponding quantities at the saturation line, we have:

$$\frac{1}{\lambda} = \frac{\log (V_s - 0{\cdot}015) - \log (V_1 - 0{\cdot}015)}{\log p_1 - \log p_s}$$

In the present case $V_1 = 2{\cdot}493$, so that $\log (V_1 - 0{\cdot}015) = 0{\cdot}3941$, whilst $\log p_1 = 2{\cdot}3766$. Then if the saturation line be crossed at a pressure of 46 lb. per square inch we find from the tables that $V_s = 9{\cdot}212$ cub. ft. per pound, so that $\log (V_s - 0{\cdot}015) = 0{\cdot}9636$, whilst $\log p_s = 1{\cdot}6628$.

Hence in this case

$$\frac{1}{\lambda} = \frac{0{\cdot}9636 - 0{\cdot}3941}{2{\cdot}3766 - 1{\cdot}6623} = 0{\cdot}7979$$

Hence by interpolation between the figures given above or directly from the expression:

$$\frac{1}{\lambda} = 1 - 0.23077\,\eta$$

we find that $\eta = 0{\cdot}8757$. The value of $\eta$ can also be found by determining the efficiency ratio $\epsilon$ from such a steam chart as that published as a two-page plate with ENGINEERING, of July 5, 1918, and taking out the reheat factor R from the diagram given in our issue of September 6, 1918, page 245. We then have $R\,\eta = \epsilon$. An ordinary Mollier chart cannot be used, since it does not have on it the curves for supersaturated steam.†

Similarly, if the saturation line be crossed at 36 lb. per square inch, we find that $\eta = 0{\cdot}7973$, whilst when the crossing occurs at 26 lb. per square inch the value of $\eta$ is 0·7206.

From Callendar's tables we get the values of $H_s$ printed below:—

| | | | |
|---|---|---|---|
| $P_s =$ | 46 | 36 | 26 |
| $H_s =$ | 652·61 | 649·69 | 645·85 |
| Work done $= H_1 - H_s =$ | 75·58 | 78·50 | 82·34 |
| Thermodynamic head expended above the saturation line $= \frac{H_1 - H_s}{\eta} = U^1 =$ | 86·31 | 98·46 | 114·26 |

To find $U_s$, the effective head below the expansion line, we employ the empirical formula already given, viz.:

$$U_s = \psi\, u_s,$$

where

$$\psi = 1{\cdot}0352 + 0{\cdot}04\,\frac{x}{100} - \eta\left(0{\cdot}089 + 0{\cdot}047\,\frac{x}{100}\right)$$

The value of $u_s$ can either be read from a chart or calculated from the steam tables in the usual way. Noting that the exhaust pressure $p_s = 0{\cdot}491$ lb., we then get the figures given below:

| | | | |
|---|---|---|---|
| $P_s$ lb. per sq. in. | 46 | 36 | 26 |
| $u_s$ F.P.C. | 154·60 | 146·02 | 134·64 |
| $\frac{x}{100}$ | 0·938 | 0·733 | 0·530 |
| $\eta$ | 0·8757 | 0·7973 | 0·7206 |
| $\psi$ | 0·9563 | 0·9661 | 0·9743 |
| $U_s = \psi u_s$ F.P.C. | 147·82 | 141·07 | 131·47 |
| $U = U' + U_s$ | 234·13 | 239·53 | 245·43 |
| Indicated work per lb. of steam, F.P.C. | 205·02 | 191·00 | 176·85 |
| Steam rate per i. kw. hour-lb. | 9·246 | 9·924 | 10·720 |

The last line but one in the above table is, of course, obtained by multiplying U by the corre-

* See "A New Theory of the Steam Turbine," page 1, of ENGINEERING, of July 5, 1918.

† Both the above diagrams are included in the reprint of "A New Theory of the Steam Turbine." A very ingenious alignment chart, by means of which $\eta$ can be determined by merely drawing two straight lines, was published in our issue of March 5, 1920, page 301. Its author is Mr. D. Halton Thomson, M.A., A.M.Inst.C.E.

sponding hydraulic efficiency, whilst the steam rate is obtained by the formula :

$$\text{Steam rate per kw. hour} = \frac{1895 \cdot 5}{\eta U}$$

In Fig. 2 the above values of $p_s$, U, and the steam rate have been plotted against $\eta$. From these curves it will be seen that, with the given initial and final conditions, a steam rate of 10·5 lb. per i.k.w.-hour corresponds to an hydraulic efficiency of 74 per cent., and that in this case the saturation line will be crossed at a pressure of about 28·6 lb. per square inch. Similarly, if we assume that the saturation line is crossed at a pressure of 30 lb. per square inch, the value of $\eta$ will be 75 per cent., and the steam rate 10·4 lb. per i.k.w.-hour, whilst the corresponding value of U (the total effective thermodynamic head) will, as the curve shows, be 243·2 F.P.C.

At a saturation pressure of 30 lb. absolute, we find from the tables that the total heat $H_s = 647 \cdot 54$ F.P.C., whilst the initial value of H was 728·19 F.P.C. Hence the indicated work done down to the saturation line is $728 \cdot 19 - 647 \cdot 54 = 80 \cdot 65$ F.P.C. and $U^1$ the corresponding thermodynamic head is therefore :

$$\frac{H^1 - H_s}{\eta} = \frac{80 \cdot 65}{0 \cdot 75} = 107 \cdot 5 \text{ F.P.C.}$$

so that $U_s$, the effective thermodynamic head, expended below the saturation line, is $243 \cdot 2 - 107 \cdot 5 = 135 \cdot 7$ F.P.C.

The total heat $H_e$ of the steam at exhaust is :

$$H_1 - \eta U = 728 \cdot 19 - 0 \cdot 75 \times 243 \cdot 2 = 545 \cdot 79 \text{ F.P.C.}$$

Hence if the steam expanded in thermal equilibrium $V_e$, its specific volume at exhaust would be given by the relation :

$$V_e = V_s \frac{H_e - t_s}{H_s - t_s}$$

where $V_s$ denotes the volume of saturated steam at the exhaust pressure, $t_s$ the corresponding temperature and $H_s$ the total heat.

At an absolute pressure of 0·491 lb. per square inch :

$$V_s = 651 \cdot 65 \text{ cub. ft. per lb. } t_s = 26 \cdot 09 \text{ deg. C. and}$$
$$H_s = 606 \cdot 58 \text{ F.P.C.,}$$

so that if the steam were in thermal equilibrium on its discharge we should have

$$V_e = 583 \cdot 4 \text{ cub. ft. per lb.}$$

In actual fact the steam, although wet, is not in thermal equilibrium at discharge, but from Wilson's observations it appears that the droplets of moisture suspended in it must be at about the saturation temperature corresponding to the pressure, whilst the temperature of the gaseous portion is on the average about that of supersaturated steam on the verge of condensing at the supersaturation limit or Wilson-line.

Table I shows the properties of steam at the Wilson line at a number of different temperatures and is reproduced, with certain minor corrections, from "A New Theory of the Steam Turbine," whilst Table II gives the properties of steam at the Wilson line for pressures corresponding to different vacua.

TABLE I.—*Properties of Steam at the Wilson Line.*

| Temperature at Wilson Point. | Pressure at Wilson Point. | Volume at Wilson Point. | Total Heat at Wilson Point. | Equilibrium Temperature. | Equilibrium Volume. | Entropy at Wilson Point. |
|---|---|---|---|---|---|---|
| $t_w$ | $p_w$ | $V_w$ | $H_w$ | $t_s$ | $y\,V_s$ | $\phi_w$ |
| deg. C | lb. per sq. in. | cub. ft. per lb. | F.P.C. | deg. C. | cub. ft. per lb. | |
| 0 | 0·9888 | 295·30 | 593·79 | 38·52 | 325·85 | 1·9098 |
| 10 | 1·739 | 173·33 | 598·28 | 49·43 | 191·50 | 1·8641 |
| 20 | 2·935 | 106·11 | 602·64 | 60·33 | 116·91 | 1·8220 |
| 30 | 4·764 | 67·339 | 606·85 | 71·24 | 74·218 | 1·7825 |
| 40 | 7·478 | 44·091 | 610·90 | 82·14 | 48·474 | 1·7476 |
| 50 | 11·39 | 29·732 | 614·75 | 93·01 | 32·666 | 1·7141 |
| 60 | 16·86 | 20·566 | 618·36 | 103·91 | 22·575 | 1·6830 |
| 70 | 24·36 | 14·531 | 621·70 | 114·80 | 15·957 | 1·6537 |
| 80 | 34·31 | 10·506 | 624·78 | 125·68 | 11·537 | 1·6261 |
| 90 | 47·80 | 7·720 | 627·56 | 136·59 | 8·638 | 1·5998 |
| 100 | 64·64 | 5·778 | 630·01 | 147·50 | 6·353 | 1·5748 |
| 110 | 86·28 | 4·389 | 632·10 | 158·43 | 4·832 | 1·5508 |
| 120 | 113·37 | 3·376 | 633·89 | 169·38 | 3·713 | 1·5278 |

TABLE II.—*Properties of Steam at the Wilson Line for Pressures Corresponding to Different Vacua.*

| Vacuum, Inches of Mercury. | Total Heat, $H_w$, at Wilson Point F.P.C. | Specific Volume, $V_w$, at Wilson Point, cub. ft. per lb. | Saturation Temperature, $t_s$ deg. C. | Vacuum, Inches of Mercury. | Total Heat, $H_w$, at Wilson Point, F.P.C. | Specific Volume, $V_w$, at Wilson Point, cub. ft. per lb. | Saturation Temperature, deg. C. |
|---|---|---|---|---|---|---|---|
| 29·0 | 588·6 | 569·3 | 26·09 | 27·5 | 595·5 | 240·3 | 42·60 |
| 28·9 | 589·2 | 520·4 | 27·72 | 27·4 | 595·8 | 231·6 | 43·35 |
| 28·8 | 589·8 | 479·4 | 29·22 | 27·3 | 596·1 | 223·5 | 44·08 |
| 28·7 | 590·4 | 444·5 | 30·62 | 27·2 | 596·4 | 216·0 | 44·79 |
| 28·6 | 590·9 | 414·5 | 31·92 | 27·1 | 596·7 | 208·0 | 45·46 |
| 28·5 | 591·4 | 388·4 | 33·15 | 27·0 | 596·9 | 202·5 | 46·14 |
| 28·4 | 591·9 | 365·5 | 34·31 | 26·9 | 597·2 | 196·3 | 46·79 |
| 28·3 | 592·4 | 345·3 | 35·41 | 26·8 | 597·4 | 190·6 | 47·41 |
| 28·2 | 592·8 | 327·2 | 36·45 | 26·7 | 597·7 | 184·9 | 48·02 |
| 28·1 | 593·5 | 311·0 | 37·44 | 26·6 | 597·9 | 180·0 | 48·61 |
| 28·0 | 593·7 | 296·3 | 38·39 | 26·5 | 598·1 | 175·2 | 49·19 |
| 27·9 | 594·1 | 283·0 | 39·30 | 26·4 | 598·4 | 170·6 | 49·75 |
| 27·8 | 594·4 | 270·9 | 40·17 | 26·3 | 598·6 | 166·3 | 50·30 |
| 27·7 | 594·8 | 259·8 | 41·01 | 26·2 | 598·8 | 162·2 | 50·85 |
| 27·6 | 595·1 | 249·6 | 41·82 | 26·1 | 599·0 | 158·2 | 51·38 |
| 27·5 | 595·5 | 240·3 | 42·60 | 26·0 | 599·2 | 154·5 | 51·90 |

From Table II we see that at a pressure corresponding to a 29-in. vacuum $V_w = 569 \cdot 3$ and $H_w = 588 \cdot 6$ F.P.C., whilst $t_s = 26 \cdot 09$, so that :

$$V_e = V_w \frac{H_e - t_s}{H_w - t_s} = 526 \cdot 0 \text{ cub. ft. per lb.}$$

The actual volume at exhaust is thus about 10 per cent. less than on the assumption that the steam is discharged in a condition of thermal equilibrium.

It may be noted here that though the bulk of the exhaust steam is at the "Wilson" temperature each droplet suspended in it is surrounded by an atmosphere of vapour at a temperature which is at about the saturation temperature next the drop, and thence rapidly diminishes to the "Wilson" temperature. Hence the above method of deducing $V_e$ tends to make it a little too small.

*(To be continued.)*

## THE CONSERVANCY OF MARSH LANDS.

By ERNEST LATHAM, M.Inst.C.E.

THE protection of low-lying marsh lands against inundation by sea or river is a somewhat specialised subject, and at times, of importance. Where there is no legal liability to maintain a sea or river wall, and the problem is one solely to be decided by landowner or tenant, the question of conserving land is frequently reduced to the consideration of the expenditure involved in reclamation or maintenance works. In the former case where land has been allowed to "go to sea" it is seldom that the problem can, in this country, be economically solved, *i.e.*, in other words the ultimate value of the land reclaimed is too low to justify the expense of reclamation. There are sometimes, however, other considerations, æsthetic or legal, which overrule this consideration; but, in general, the wise policy is to "maintain" and therefore not to have to "reclaim."

Many marsh areas are under the control of Sewer Commissioners. Where this is the case, though sometimes heavily rated, sea and riverside properties are fairly immune from inundation. Breaches, however, have occurred from time to time in embankments maintained by Sewer Commissioners, *e.g.*, in the Parish of Stone, Kent, in 1896, and the same year on the Fobbing Levels, Essex. The administrations of these independent bodies of Commissioners are by no means standardised, and their boundaries are somewhat haphazard. It is to be hoped, however, that under the wide powers of the Drainage Act of 1918, areas may be merged, new areas created, and powers vested in County Councils in such a way as to ensure the consistent protection and drainage of all low-lying lands in Great Britain.

At the time of writing certain definite steps have already been taken by the Board of Agriculture and Fisheries, notably in respect to the Rivers Ouse, Crouch and Blackwater, in East Anglia.

*Clay Embankments.*—The type of embankment on the Essex Flats is more or less standardised. A dyke is cut at the back of the bank, into which the main outfall channels are carried, and these discharge the drainage of the marshes through sluices in the wall; these sluices are provided with tidal flaps at their seaward end. The level of the marshes generally averages from 7 ft. to 10 ft. below high-water level, and the back slope of the embankment, though supposed to be 1½ to 1, is more generally 1 in 1. The crest of the bank averages about 3 ft. wide, and the outer slope starts at 1½ to 1, either until it meets the natural protective saltings or an easier gradient (about 5 to 1) leading on to the natural foreshore. The sea or river face of the wall is pitched with block chalk or Kentish ragstone, or both, sometimes from the crest to the toe, and sometimes only from high water level to the toe. Where the protective saltings are wide, and the sea or river face of the wall consequently short, this protective pitching is sometimes omitted; where no saltings exist, the toe of the slope is protected—either by light elm piles or random stonework dumped in mounds on the foreshore. Rough attempts at groyning are also sometimes carried out. It is useful to quote the above typical section, because similar protective works are also found on the Kentish coast, on the Norfolk and Suffolk rivers, on the banks of the River Severn, in Ireland, and elsewhere.

*Breaches.*—The greatest threat to which this class of protective work is exposed is that of a breach. This form of failure may occur in any of the six following ways :—

(A) By damage to pitching, owing to the impact of waves.

(B) By subsidence of the wall forward, owing to scouring action below high water mark.

(C) By subsidence vertically downwards.

(D) By subsidence of the wall landwards.

(E) By constructional work such as wharves, factory foundations, or other riverside works.

(F) By erosion on the face of the bank, caused by direct wave action.

These classes of failure are dealt with *seriatim* below.

*Class* A.—It will be found that damage to pitching is of very common occurrence. In the winter of 1912, during a gale from the south-east, considerable quantities of pitching on the north bank of the River Thames were dislodged and breaches in the embankments threatened. Only prompt action by the Commissioners' surveyor on this occasion saved the situation. Damage is progressive in the following order. After the pitching has been dislodged, wave action or scouring action of the tide rapidly takes out the clay hearting from behind; the crest of the wall then subsides, and the next high tide flows over the crest thus lowered; the first trickle of water quickly becomes a torrent, and weir action takes place inside the wall. Although the water may be quite shoal outside the bank, it is not at all an uncommon thing for the digging action of the water to bore a depression in the marshes 40 ft. or 50 ft. deep, into which the adjacent banks then slide. A single tide is sufficient, in some cases, to complete the damage. This digging or boring action of the water renders the repair of such a breach most difficult. To repair a breach which is only threatened in this way is an easy operation. Where the evil has been allowed to go on, the cost of reparation, however, becomes extremely high. A breach of this kind was recently closed on the River Crouch, reclaiming an area of about 300 acres. The work was carried out by unemployed labour, and cost about 27,000*l*. This perhaps, is not quite a fair figure to quote, as unemployed labour is always expensive. The engineer retained in this case estimated the cost of the work under ordinary contract conditions to be approximately 9,000*l*., but even this latter figure was, in the instance referred to, disproportionate to the value of the land reclaimed.

The author reported on such a breach on the River Deben, in 1913, but the cost of closing it was out of all proportion to the value of the land.

Another example of this class occurred at St. Osyth, Essex. In this case there were some 250 acres of low-lying land threatened with inundation. The two photographs reproduced on page 4 illustrate the condition of this frontage: 350 lineal ft. were similar to the photograph (Fig. 1) and 1,400 lineal ft. like the photograph (Fig. 2), at places even

worse owing to the complete demolition of the timber facing by decay preceding wave action. Figs. 3 and 4 give the respective typical cross-sections, and Figs. 5 and 6 the proposals for refacing the embankment in reinforced concrete. The site is at the estuary of the River Colne where it joins the sea, and the tidal conditions were of special interest, failure being due to a combination of scour and wave action. This case was also a classic example of the necessity of determining the economic relationship between the expenditure necessary to embankment to move forward with it. Under an old Act, the wharfingers sought to recover part of the cost of reparation from the adjacent landowners, and an action in respect of this was heard before the Official Referee in the High Courts in 1908, when a verdict was given in favour of the plaintiff. As a consequence of this judgment, the landowners concerned are held liable to meet all such charges which are likely to accrue in the future. In view of the mode of reparation adopted the trouble is likely to be progressive, and the position of the con-

*Class* C.—This class of subsidence in clay embankments involves a most careful investigation as to the nature of the underlying strata. It is sometimes due to pumping operations and occasionally due to dredging. In a recent case coming under the author's notice in Monmouthshire, dredging operations 4,000 ft. away from the river bank produced a settlement of 12 in. vertically downwards within a period of eighteen months. Such an occurrence is a serious matter where low-lying lands are involved; a few inches will suffice to

FIG. 1.

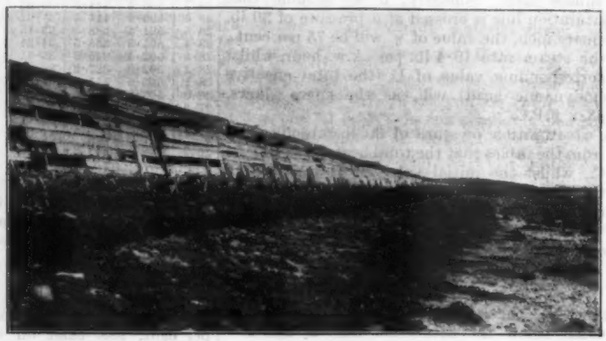
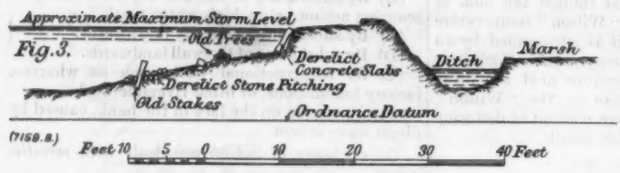
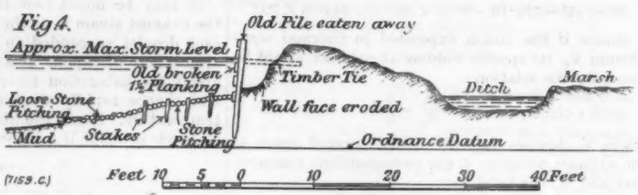
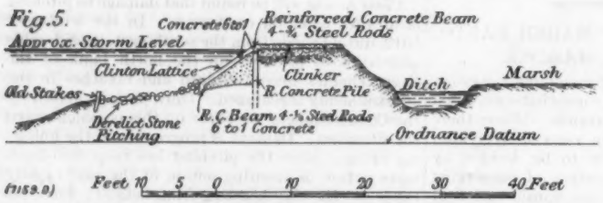


FIG. 2.



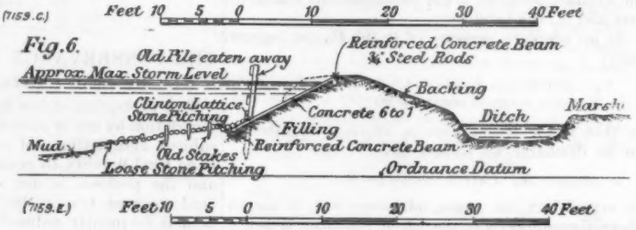



FIG. 7.

FIG. 8.

reinstate the wall and the value of land protected, which in this case and at that time probably did not exceed 20*l.* per acre.

*Class* B.—An example of class B was that of a slip occurring to an embankment on a property at Purfleet. The owners in this case constructed a jetty, with its berthage parallel to the river bank. The approach works of the jetty were carried on reinforced concrete columns 5 ft. in diameter, which columns deflected the set of the ebb tide inwards onto the river bank. This action scoured away the foreshore and disclosed a very unstable formation, known locally as "moor-logg"; this formation sliding forward into the river caused the tributory landowners is, therefore, not an enviable one. An extensive marine survey was undertaken in connection with this action, the result of which, in the author's opinion, conclusively proved considerable scouring action to have taken place. The statement, therefore, put forward by the defendants though not accepted by the court, would appear from the engineer's point of view to be correct—namely, that the only possible method of arresting the movement of the bank was to carry out protective works on the foreshore in front of the wall, at or near low water mark, and by the grading and facing of the river bank from that level backwards and upwards to the crest of the wall.

endanger the safety of protective embankments. Directly settlement is suspected, periodic observation should be undertaken at once at regular intervals in order to establish evidence between cause and effect; borings may also sometimes have to be undertaken. Very little can be done to arrest this class of subsidence, as the marshes and foreshore usually accompany the wall in its downward movement. If, however, it can be established that no appreciable settlement had occurred over a period of years prior to the dredging or pumping operations, the parties responsible for the latter can usually be restrained by legal process.

One exceptional case of subsidence vertically

downwards occurred on the sea wall at Leysdown, Isle of Sheppey, Kent, immediately following the armistice terminating the great war. During 1917 and 1918 the Air Force stationed in the island at Eastchurch and Leysdown utilised the foreshore in front of this sea wall as a practise ground for bombing from aeroplanes with high explosives. The foreshore here consists of London clay and is over a mile in width at low water. Practice targets were anchored on the foreshore, and a continuous rain of bombs fell on it for two years. Frequently bombing was continued when the foreshore was dry, causing craters some 10 ft. or 12 ft. deep within about 300 yards of the apron of this wall. The profile of the wall itself is shown in Figs. 7 to 9, and it consisted of London clay pitched on the surface with stone and grouted in with sand-cement. An approximate section is shown in Fig. 10. The normal expenditure on this wall for many years had not exceeded 100*l.* per annum, but, as the result of bombing, the expenditure in two years rose to over 3,000*l.* Failure was caused apparently by the particular case the movement was arrested by an immediate dumping of material behind the wall, thus easing the slope and reducing the earth pressure. Where this form of slip does occur, it is usually after heavy rains, or due to the jamming or failure of sluices, permitting the entry of river or sea-water on each side. The marshes are then liable to become "soggy," and the movement starts by subsidence at the heel of the wall.

*Class* E.—Little can be said with regard to breaches threatened in the manner indicated under class E, beyond noting the fact that the trouble usually arises from the overloading of the wall in some form. Several instances of this have come under the author's notice, but as the problem in each case presents a different aspect, it is impossible to generalise. The stability of most foundations on marsh lands depends on the even distribution of their loading, and failure to comply with this physical requirement has frequently been the cause of considerable settlement in buildings and adjacent earthworks.

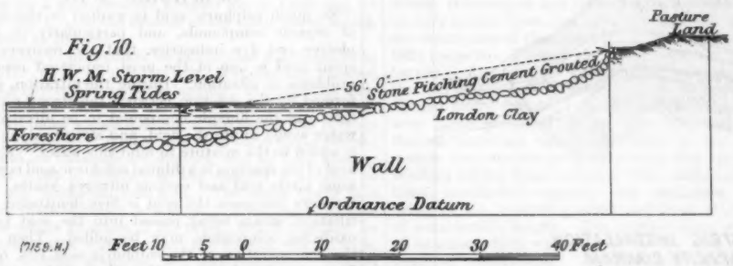
with success on the banks of the Rivers Thames,* Medway, Crouch, Alde and Blyth. The second substitute is the Decauville system, of which the author has no personal experience; in cases where earth pressure from behind is encountered, it would appear to serve a useful purpose—more especially where the banks are steep.

*Reparation of Breaches.*—Where complete breaches in clay embankments of the kind under consideration have occurred, their repair is a most difficult question. All sorts of ingenious devices have been suggested and tried, but have generally been conspicuous by their failure. Measures such as the sinking of barges in the gap, or attempts to cross the breach by sheet piling alone, are generally to be condemned. In many cases they serve only to widen and deepen the breach as work progresses.

A sound policy to pursue is often deliberately to remove the banks for some distance on either side of the breach, which permits of an easy influx and efflux of tide, in place of the gorged current through the original breach. The pot-hole cut by the inward

FIG. 9.

FIG. 11.




radial impulse of explosions passing through the fabric of the wall and causing the clay to settle in places. The extent of this settlement reached 3 ft. in the worst cases, and the surface of the apron collapsed into the cavities so formed. Fig. 11 gives a close view of the pitching which the Air Ministry maintained was in bad condition, and the prime cause of collapse. While, however, this particular section of wall admittedly required the usual attention which maintenance of this class of wall calls for, there was, in the author's opinion, no evidence that its condition had in any way been abnormal prior to the commencement of bombing practice on the adjacent foreshore. The curious fact about this failure was that no cracks occurred on the surface of the wall, nor was there any evidence of clay from behind the pitching being washed out, failure coming suddenly in the form of collapse of the pitching into the cavities as above described.

There is little doubt that this failure was directly attributable to "wave action" in the deep strata of London clay, and the recent experimental investigations made by Mr. A. S. E. Ackermann, B.Sc., indicate that the detonation of high explosives momentarily reduced the clay to a fluid state owing to the high local specific pressure exerted radially through the strata.

*Class* D.—The class of failure referred to under D is uncommon, and the author in his experience has had only one such case to deal with. In this

*Class* F.—The phenomenon met with under F is of frequent occurrence. One case with which the author dealt was in connection with the protection of a considerable stretch of river embankment on the north side of the River Alde. For some time, up to the year 1910, owing to wave action during high tides, this embankment had been rendered nearly vertical on its river face, and in some places it was actually of a concave formation. The bank was first faced with carefully selected clay puddle to an even slope of 1 in 1½; some old timber piling at the foot of the wall was cut to a level uniform with the foreshore and then backed with mass concrete.

Behind this, in place of the usual chalk and ragstone pitching (in this district known as stud and plaster work), keyed concrete slabs were laid on the De Muralt system. It was found that this system readily accommodated itself to the curves and re-entrant angles of the river bank. It is more durable and scour-proof than ordinary pitching, and in the case quoted met with complete success. In view of the economical character of the work, the owner of this property extended the facing down river in 1911, and again in 1912; in all, there are now some 2,000 lineal ft. of this bank so protected, and it forms a useful object lesson.

*De Muralt and Decauville Facings.*—There are, apparently, only two effective substitutes for chalk or stone pitching in vogue; one is the De Muralt system referred to above, which has been employed

rush of water can be filled from hopper barges, or by dumping material overside from other floating craft at or near high tide; the bank can then be reconstructed in upward steps of a foot or 18 in. at a time over the whole width of the widened gap, due precautions being taken to prevent the removal of material by each successive tide. Another, although more expensive alternative, is that of a temporary timber dam, driven seawards of the gap and provided with an efficient sluice, or sluices, so that the flooded areas can be drained and reparation take place behind the protective dam.

A common operation resorted to in such cases is that of constructing an inset clay embankment, effecting junctions with the old wall on either flank of the breach; indeed, owing to questions of cost, it is this last alternative which is usually adopted. It is, however, unsatisfactory, because it creates awkward re-entrantment angles to the alignment of the wall, which are likely sources of future trouble, while a certain area of land between the inset and original alignment of the old wall has to be permanently abandoned.

*Tidal Hydro-Electric Problems.*—At the time of writing, some amount of public attention has been called to the problem of utilising tidal power. As efficient turbines are now procurable for operating under very low heads, the possibility of utilising otherwise waste marsh lands for tidal storage is of interest. The class of work involved by proposals for establishing tidal hydro-electric installations whereby the great reserve of tidal energy may be converted to "the use and convenience of man" has always been a fascinating subject to engineers, but as no practical example on a large scale exists, the actual financing of such schemes has always presented difficulty. Many so-called tide mills have been in existence at different periods, notably at Bishopstone, near Newhaven; St. Osyth, Essex; and on the River Rance, Brittany. They are all quite distinct from the hydro-electric installations of the American Continent, where the hydraulic "flow" is always in

* *The Engineer*, July 15, 1910, page 71.

one direction and where the civil engineer's province is restricted to the study of river discharges and the design of suitable head and tail races with their accompanying accessory works. Such installations depend primarily on the use of river discharge and differ fundamentally from any attempt to "harness the tides." In this country the subject was brought forward prominently by Sir Eric Geddes in the House of Commons on November 30, 1920, when replying to questions concerning the then proposed establishment of a hydro-electric scheme on the River Severn. There appeared to be many, and perhaps insurmountable, objections to that particular scheme, and it was not truly "tidal" in that the source of power comprised two factors, viz. :—

1. The natural effluent due to the rainfall in the River Severn catchment area.

2. The tidal effluent due to the volume of tidal waters impounded twice daily behind the proposed barrage.

The first factor represented a pure river hydro-electric proposal and the second a pure tidal hydro-electric proposal and it is well clearly to differentiate between the two. The maritime engineer, if we properly understand the definition of his calling, has nothing to do with the first class of undertaking, but is intimately concerned with the second.

Early in 1921 the author was asked to investigate a proposition for establishing a hydro-electric installation in the Island of Mersea, Essex. The scheme was first looked askance at as being of a visionary character. The promoter of the idea was not an engineer and, therefore, naturally suffered from certain disabilities, including the want of a proper realisation of the fact that any hydro-electric scheme must of necessity be devised on the lines of continuous output, intermittent supply being useless except in those industrial centres where the supply of power, though intermittent, can be balanced to some extent at a central station. This latter possibility did not present itself at Mersea.

There was some difficulty in convincing the promoters that, because 5,000 h.p. was running to waste daily, it might be difficult to "harness it," and even it out over the 24 hours! By chance the topographical character of the country, however, did lend itself to an enterprise of this character. The diagram, Fig. 12, to some extent explains this when taken in conjunction with the plan, Fig. 13. The Island—a reduced edition of the Isle of Wight—is separated from the coastline by two channels—the Strude Channel and the Pyefleet Channel. These channels penetrate low-lying marsh lands protected by clay embankments, and which, if flooded by intentional breaches in the river banks, would give a potential head of water for power purposes. The range of spring tides was about 14 ft., and neaps some 4 ft. less, so that an effective working head of 5 ft. could be provided with horizontal type turbines over about half the tide cycle.

*Fig.12.* HYDRO-ELECTRIC INSTALLATION DIAGRAM.

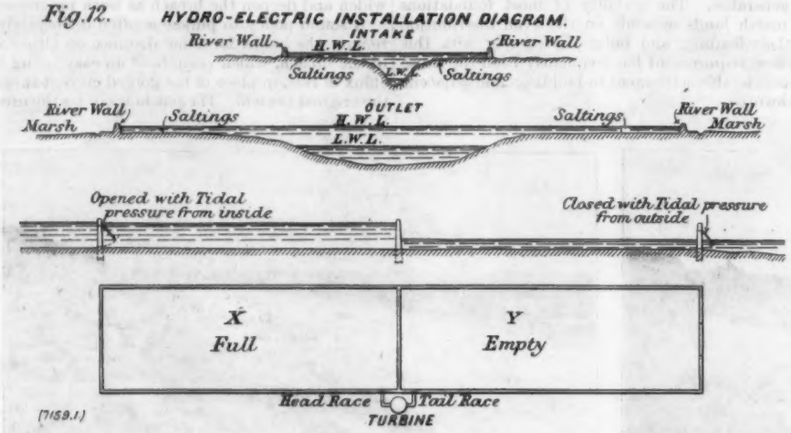
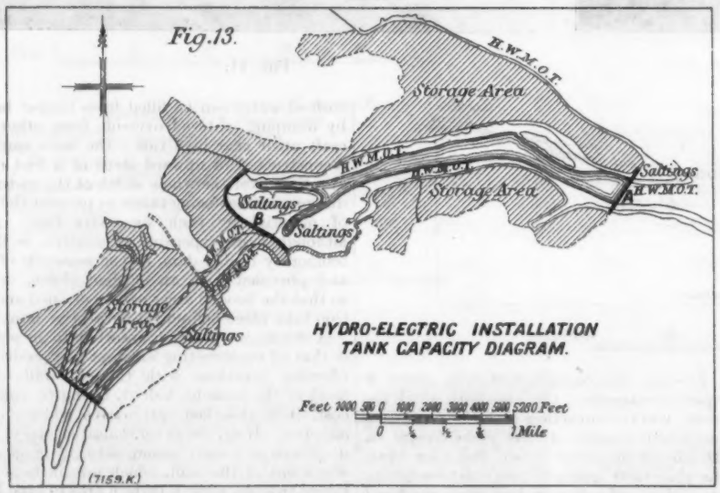



*Fig.13.*




The proposed scheme has not at the time of writing been carried out, but there is no doubt with the demand for cheap power rapidly growing tidal hydro-electric schemes in general will pass from the visionary to the concrete stage sooner or later. The investigation made at Mersea Island clearly shows, however, that suitable sites for tidal hydro-electric schemes are limited by the topographical characteristics of the coast line, and that prospecting for such sites will become quite a special branch of maritime engineering in the near future.

Interesting examples of turbines working under low heads (down to 12 in.) already exist at the Chester Corporation power station, and on a small scale at Sir John Anderson's model farm at the village of Harrold, Bedfordshire.

The flooding of marsh lands for the purpose of establishing hydraulic power schemes will entail a very careful study of existing river and sea embankments as the pressures on the embankments will be reversed, *i.e.*, they will be experienced on the backs of the river walls and be continuous instead of being on the faces and intermittent with the rise and fall of tide. Suitable protection in the way of pitching or facing the land slopes, and in certain cases strengthening of the wall sections, will undoubtedly be found necessary.

The French Government, after a long study of the subject of utilising tidal energy for power purposes, has selected the estuary of the River Rance as being the most promising site for initiating a tidal hydroelectric enterprise, but here there is no question of utilising marsh lands for "storage purposes."

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There being no natural site for a high-level reservoir for storage to cover the other half of the tide cycle, it appeared necessary to seek for a low-level empty compartment to take discharge during the otherwise inoperative period.

An hydraulic scheme was devised in accordance with Fig. 12, where Y, the empty compartment, was closed by tidal pressure from without and was intended to provide the reserve capacity. By coincidence at low tide the Pyefleet Channel, according to the Ordnance sheets, showed a possible capacity as an "empty compartment," without dredging, of 36,000,000 cub. ft., and a general scheme on the lines of Fig. 13 appeared possible, though limiting the initial scheme to about 1,000 h.p.

The works proposed were :—

(*a*) The construction of two barrages across the entrances of the Pyefleet and Strude Channels at A and C. (See Fig. 13.)

(*b*) The construction of a clay bank B dividing the supply and discharge areas. (See Fig. 13.)

(*c*) The construction of a power-house with the necessary turbines, generators and accessories, and the necessary sluices and races.

## THE CONCENTRATION OF WASTE SULPHURIC ACID.

So much sulphuric acid is wanted in the nitration of organic compounds, and particularly in the explosive and dye industries, that the recovery of the spent acid is one of the most important economical problems in nitration. During the nitration, water is formed by the reaction between the strong nitric acid used and the organic compound to be nitrated. The water would dilute the acid, and strong sulphuric acid is added to the mixture to bind this water. The spent acid of the reaction is a diluted sulphuric acid containing some nitric acid and various nitrogen oxides. In the recovery processes the acid is first denitrated by distillation, steam being passed into the acid to which oxidising compounds may be added. Then follows the concentration of the sulphuric acid left, of about 70 per cent., which should be brought up to 96 per cent. again, if possible, for re-use in nitration. This concentration is effected on the lines of the sulphuric acid manufacture.

In the olden days the diluted acid was heated in lead pans, either over the fire or by the hot flue gases passing over the acid; the final concentration to the highest strength was carried on in vessels of platinum, glass or cast-iron. Later, glass and iron were replaced by silica and by silicon-iron alloys which resist weak sulphuric acid better than cast-iron, whilst the latter bears strong acid much better than weak acid. A large use was made of small pans of silica or silicon-iron arranged in cascade: big works relied chiefly on contration in towers, of the old Glover type or of the more recent Kessler and Gaillard furnace types. Before the war the Kessler was the most common and successful of these apparatus, but the various Kesslers differed much in detail. The Kessler is a small square tower, about 10 ft. high, built up of four or more frames of iron, superposed upon one another and upon the base of the tower, which is known as the saturator; it is built of volvic lava. Each of the frames, together with its perforated bottom and baffles, serves as a shallow pan; the acid enters at the top, and trickles down through the perforations, which are covered by calottes, to meet the hot gases from the producer, which are admitted into the passages of the saturator.

When the war broke out, neither Kessler plants, nor Gaillard towers—which may be characterised as a combination of the Kessler with the old Glover tower—could be delivered with sufficient speed. Cascade plants of silica and silicon iron were hence erected in the new Government factories. In these plants a series of small basins are so set into the top of an inclined flue, that each basin delivers its acid, fed in

continuously at the top, through a spout into the basin below; the flue is heated from a furnace at the lower end of the flue, which is covered in while the upper portion may be left open; in the lower basins the acid may almost be boiling. The acid fumes are drawn through a coke scrubber, but they are apt to cause complaints especially when a basin becomes cracked. Many thousand tons of acid were concentrated in cascade plants. Some of these were afterwards replaced by Gaillard towers, which Mr. W. Macnab, in his report on "Sulphuric Acid Concentration,"* considers one of the best, if not the best, apparatus for this purpose. The Gaillard process, and the similar Gilchrist process, also adopted, underwent considerable modifications at Queen's Ferry and in the other Government works; in both cases the acid mists discharged had to be treated by the Cottrell fume-precipitation process. Mr. Macnab describes these three processes—all patented—and their operations, dwelling particularly upon heat balances and physico-chemical features. The constructive detail, ample mostly, is meagre in some parts. Success will largely depend upon the ingenuity and care bestowed upon installation and working, and as much hence upon the engineer as upon the chemist.

Though the Gaillard patents go back to 1906, the technical process was practically novel to this country. The complex circulation is the characteristic feature of the process, and the modifications spoken of affect this circulation in particular. The Gaillard plant at Queensferry consists of two batteries, each of eight towers, each complete with furnace, recuperator, &c. The diluted acid is gravitated into a series of blow-casks (horizontal acid eggs), set in pits in front of the towers; by compressed air the acid is forced through nine atomisers, mounted in the dome of a tower, and also through six atomisers in the top of its recuperator next to it. The acid spray descends freely in the tower, meeting the hot gases, deposits its impurities (compounds of lead and iron) in a mud box, and flows into an acid tank. The offtake pipe conveys the vapours from the top of the tower either to the top or to the bottom of the recuperator; the former, counter-current flow was later abandoned in favour of the latter, concurrent flow. From the recuperator the vapours are drawn through a scrubber and fan into the Cottrell conduit or treater, finally to be sent back to the recuperator. The heating gas, of moderate calorific value, comes from a producer, is burnt in a combustion chamber and drawn by a high-pressure Kestner fan at 1,000 deg. or 1,100 deg. C. into the bottom of the main tower, which it leaves at 200 deg.

Turning to particulars we notice that the combustion chamber, 5½ ft. by 6 ft. by 4 ft., is completely encased in steel covered by asbestos lagging; it is supplied with producer gas through three 8-in. mushroom valves, the two outer valves leading to the rear of the furnace at the base of the chamber, the third valve to the centre; gas and air channels are distinct, and all local heating at the point of mixture in the channel is avoided so that the bricks do not melt. The main tower is a hollow shaft of volvic lava stone or firebrick, built with toggle joints in rings, 3 in. thick, bound together by circumferential steel hoops; the towers, 47½ ft. high, 13 ft. internal diameter, are best completely covered with lead; the inside of the tower is not packed in any way. The recuperator is a column 30¾ ft. high, 5 ft. external diameter. In the Gretna works the recuperator towers were finally replaced by vertical boxes, 11½ ft. by 6 ft., 10¾ ft. high, lined, like all these parts, with lead; the offtake pipe, 24 in. diameter, from the main tower, goes to the bottom of the box, in which it is made of obsidianite, and the gases force their way through a multiple false bottom of checker brickwork and several layers of quartz to enter the main body of the box which is packed with 3-in. pottery rings, the spaces of which are arranged vertically. In the final method all denitrated acid was first passed through these box recuperators.

The main point in the Gaillard process is that the hot gases come into direct contact with the acid spray, instead of bubbling through the acid. The degree of concentration can be raised by reducing the diameters of the orifices of the spray plugs without altering the number of plugs; the orifices range in steps of 0·1 mm. from about 5 mm. to 6 mm., these being the usual dimensions; details of the plugs are not given. Temperatures are controlled by means of pyrometers. In calculating the amount of heat required to concentrate an acid of 65 per cent. up to 92 per cent., *e.g.*, and in drawing up the heat balances, the tables and diagrams of Professor A. W. Porter's paper on "The Thermal Properties of Sulphuric Acid and Oleum"† have been of great service. As we said, Mr. Macnab discusses the heat losses and efficiencies observed under different working conditions at considerable length. One does not gain the impression that the control can be easy. During the four half-years 1916 II to 1918 I, the production of sulphuric acid at Queen's Ferry rose from 29,099·5 tons to 68,798·9 tons, the acid losses decreased from 7·9 per cent. to 2 per cent. and the total cost increased from 1·393*l.* per ton in 1916 II to 1·426*l.* in 1918 I; but the last figure was high owing to plant alterations, and the cost had been down to 0·895*l.* and 0·984*l.* in 1917 I and 1917 II. The acid concentration was about 90·7 per cent., rising to 92·0 per cent. in the last half-year.

The Gilchrist plant [the rights of which are controlled by the Chemical Construction Company of Charlotte, Carolina, U.S.A., represented in this country by Messrs. Huntington and Heberlein, of Westminster, who also represent the International Precipitation Company of Los Angeles as to the Cottrell rights] at Queens Ferry consisted of two units each to deal with 65·5 per cent. acid (from the cellulose nitration) and to yield 70 short tons of 93·5 per cent. acid or 35 tons of 97 per cent. acid per day by using 162,000,000 B.Th.U. There are again two towers in each unit. The main tower, 47 ft. high, 15 ft. wide, which overtops a shallow pan, the saturex, is packed with quartz and pottery rings through which the acid trickles down into a pan over which the hot gases from the furnace pass; the strong acid flows out of the pan at the end where the gases are admitted. The hot gases are taken over to the filter tower, 31 ft. high, also packed with quartz over a checker-work bottom, where they again meet weak acid. The main trouble with the Gilchrist plant was the excessive wear on the base of the tower and in the saturex. The furnace gas temperature never exceeded 850 deg. C., but the lead work had to be renewed completely after five months' run; the sludging of the units also caused difficulties.

We mentioned already that both the Gaillard and the Gilchrist plants had to be combined with Cottrell fume precipitators. The Alkali Inspector's report of 1918 complained about unduly high escapes of acid vapours from Gaillard towers, at a time when modified Kessler plants did highly satisfactory work and the cascade system continued in existence with varying experience. The Record No. 3 does not state the acidity of the air; but it is mentioned that for every 60 tons of acid received from the recuperators, 3 tons came from the scrubbers and 2 tons from the precipitation treaters. The treaters were installed by Messrs. Huntington and Heberlein, as at Holton Heath, on very similar lines, and we would refer our readers to the description of that plant in our issue of January 28, 1920 (page 96). Though the Queensferry Cottrell plant for the Gaillard towers was projected on a larger scale, the four treaters, each 30 ft. by 7½ ft. by 8½ ft. height, did not prove sufficiently large, and two more treaters were later projected of an improved design. The Record describes the construction of the treaters, mainly concrete and lead, very fully, and discusses the troubles arising from weakness of the walls and foundations, insufficient capacity and insulation, cold air rising in the insulating shaft and from other causes, at considerable length. The rectifier discs were made of bakelite which was charred by the acid mists and rendered conducting; another disc material was adopted at Holton Heath. The fumes enter the treaters at about 90 deg. C. and travel at the rate of 3·1 ft. per second, the reaction time being about 10 seconds. About 30 tons of 51 per cent. acid are recovered per day, and 1·2 per cent. of the acid still goes up the chimney shafts; the Cottrell efficiency is estimated at 70 per cent. to 75 per cent. The treaters are closed down for 10 hours every 8 or 10 days for burning out the flues and for repairs.

Most of the big Government factories are now closed or are worked on a small scale. The information given in Record 3 on the plant and operation, combined with that in the previous Record 2 on cost and efficiencies, are all the more welcome. The regulation of the circulation of gas, vapour air and acid, the temperature control and the heat balances are important problems which were successfully solved in these plants, and about these matters the physical chemist will elsewhere find little guidance, even in special treatise on acid manufacture.

* Technical Records of Explosives Supply, 1915–18. No. 3, Sulphuric Acid Concentration. Published for the Department of Scientific and Industrial Research, by H.M. Stationery Office. [Price 12s. net.]

† Trans. Faraday Society, Vol. XIII, Part 3, 1918.

## NOTES ON NEW BOOKS.

While the discussions on the problems of ore flotation have of late quieted down in this country, a good deal continues to be written on the subject in America. In his volume on "*Concentration by Flotation*" [New York, John Wiley and Sons, and London, Chapman and Hall, Limited; price 42*s.* net], Mr. T. A. Rickard republishes more than 20 recent papers on flotation, contributed by various authors, chiefly to the "Mining and Scientific Press," together with some new articles from his own pen. The different papers are independent and overlap to a certain extent. The volume of 692 pages opens with a glossary of flotation and passes on to the history and the principles of the flotation of gold and silver minerals, and to flotation litigation. These sections, as well as subsequent articles on present-day practice in Utah and on the smelting of flotation concentrates at Garfield, are by Mr. Rickard himself, whose previous book on the "Flotation Process" and cognate papers are well known. Among the other authors we notice O. C. Ralston and Glenn L. Allen (on ore-testing for flotation, mechanical developments, differential flotation, and the flotation of oxidised ores); Charles Butters and J. E. Clennell (on cyanide treatment of flotation concentrates); W. E. Simpson (on flotation at Cobalt); A. H. Heller and H. L. Hazens (on the Horwood process as applied to copper-zinc ores); E. T. Henderson and also James Hebbard (on flotation at Broken Hill); R. T. Mishler (on flotation in Mexico); and H. Hardy Smith, W. H. Coghill and others on theoretical points. The *resumé* at the end of the volume, by H. R. Adam, of the South African Mining Society, also deals largely with theoretical points; we notice that several of these writers seem to be less impressed with Sulman's researches than some professors were over here; but all flotation is *per se* "differential." Mr. Rickard himself considers that the theory and practice of flotation is still too imperfectly understood. That conclusion might have induced him to give statistics on the growth of flotation, but there is no statistical section in the book.

In the case of firms manufacturing a speciality there is a good deal to be said for the practice of publishing a handbook dealing with their product from the technical point of view. Such a book possesses a permanent interest and value which is usually wanting in a catalogue pure and simple, and it will be retained as a work of reference, to the advantage both of the user and the manufacturer of the particular product dealt with. In "*Machine-Cut Gearing*," published at 25*s.* by Messrs. David Brown and Sons, Limited, of Lockwood, Huddersfield, we have an excellent example of the kind of work to which we refer. Within a compass of about 200 well-printed pages, there is collected a lot of very useful information about gearing of all kinds—spur, bevel, helical, and worm—with the principles of design and the methods of manufacture clearly explained. The book is decidedly a useful one, and the numerous tables dealing not only with gearing but also with mathematical and mechanical quantities frequently required for engineering calculations, will add to its value in a designer's office.

One of the German standard books on the governing of power engines, Dr. Max Tolle's "*Regelung der Kraftmaschinen*," is now before us in its third edition [Berlin, Julius Springer, price 240 marks plus 100 per cent.]. Dealing with the calculation and construction of flywheels, of mass balancing devices and of governors, Dr. Tolle, professor at the Technical High School, Karlsruhe, writes for the student and designer rather than for the actual contractor. In this third edition of 889 pages, illustrated by 532 text figures and 24 tables, well printed on superior paper, Dr. Tolle might perhaps have left out reference to some obsolete types; he has not done so when those types exemplified the devious way by which progress was achieved. On the other hand he has made important alterations and additions, besides carefully revising his volume. Unfortunately an alphabetical index is still wanting; this is not an unimportant point, since one has to study the book for some time before one knows where to look for a certain governor. The chapters on flywheels and the influence of the number of spokes on the steadiness of the run of railway engines and on torsional vibrations, have been re-written. As regards torsional vibrations many observations were taken on submarines and flying machines, and Dr. Tolle has modified the treatment of these problems which Dr. Gümbel described before the Institution of Naval Architects in 1912, and which Geiger simplified in 1915. Dr. Tolle makes his calculations of shafts, consisting of several sections of different lengths and diameters, supporting heavy masses at different points and driven by several engines, by determining the moments and amplitudes in the "forward-backward" way, i.e., by starting first from the one end of the shaft and then from the other. He claims that he can in this relatively simple way calculate the result of any proposed alteration in the mass distribution. Examples are worked out.

Almost every lecturer, when mapping out his courses of work for his classes, finds difficulty in recommending for each class a single volume as a text book. The reason for this trouble is that text books are written for a dual purpose: firstly to provide a book suitable for a particular class of students that the author has to deal with himself and secondly, to be sufficiently exhaustive in treatment to appeal to engineers outside the student age, in whose libraries the author hopes to find a place for his work. Compromise in treatment is in consequence necessary, and

as a result the book is unbalanced, being better in one section than another for each particular reader. As a student's work it may suit the particular class it was written for, but classes in other colleges may have different standards of preliminary training and the lengths of courses may vary. Mr. C. G. Lamb, M.A., the well-known lecturer in the Engineering Department of Cambridge University, has attempted, with great success, to get over this difficulty with the subject of "*Alternating Currents*," by providing two volumes which aim primarily at assisting students in writing up and understanding their notes of the work of their classes. These books are not written as text books in the ordinary sense, but aim at a concise explanation of the main principles of alternating currents and treat the subject in such a way that they provide an admirable introduction to the larger works on electrical design. Part I concerns itself with the more elementary theory, starting with the nature of alternating currents, the effect of inductance and capacity in the circuit followed by a consideration of eddy current losses, the ideal transformer, vector diagrams and alternating current instruments. Part II treats of the production of electromotive forces in coils, the forms of windings, the effects of harmonics, the investigation of wave forms by the oscillograph, the theory of monophase and polyphase machinery, regulation, synchronising and the rotary converter. The Cambridge University Press publish these volumes at 5*s*. 6*d*. net for Part I and 12*s*. 6*d*. net for Part II. The author is to be congratulated on the clear way in which he has treated his subject-matter. A student of alternating currents in any college will find these books need no shelf room, as they will usually be found at his elbow on his desk.

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The exceptional scientific and industrial importance of the general discussion on "*The Physics and Chemistry of Colloids and their Bearing on Industrial Questions*," which was held on October 25, 1920, jointly by the Faraday Society and the Physical Society of London, induced the Advisory Council of the Department of Scientific and Industrial Research to recommend publication of a full report of this discussion by H.M. Stationery Office. The report now published is priced at 2*s*. 6*d*. net. We dealt with the Colloid discussion at some length in our issue of October 29 and November 5, 1920. The *extenso* report contains further contributions to the discussions, by Dr. Wolfgang Pauli, Vienna, on "The General Structure of Colloids"; by Professor Zsigmondy, of Göttingen, on "Elastic Gels"; by Dr. Wolfgang Ostwald, of Leipzig, on "Dipersoid Analysis of Non-Aqueous Systems"; by Dr. Jacques Loeb, of the Rockefeller Institute for Medical Research, Chicago, on "Proteins and Colloid Chemistry"; and by Dr. H. Knecbone Tompkins, on "The Internal Pressure of Liquids." This last-mentioned paper was written in 1896 as an inaugural dissertation for the degree of doctor of science, London; as it was never published, the Joint Committee decided to add the results of this investigation of historical importance by an early and accurate worker in the field of colloidal physics, to this volume. The paper deals experimentally with the swelling of rubber in various solvents and theoretically with the analogies between the properties of caoutchouc and other colloids and of metals, that is to say, metals in the ordinary condition, not only in the colloidal state.

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## 6-FT. HIGH-SPEED RADIAL DRILL.

THE radial drill illustrated in Figs. 1 to 9, on the present and opposite pages is the 6-ft. size of a range of machines manufactured by Messrs. George Swift and Sons, Limited, Claremont Ironworks, Halifax. Other sizes of this type of machine run from 4 ft. 6 in. to 8-ft. radius. The usual motions for drilling, tapping and studding are embodied in the design, of which a general idea will be obtained from the photograph reproduced in Fig. 1, and the elevations given in Figs. 2 and 3. Various details are given on page 9, Fig. 4 showing the column in section, Fig. 5 the main drive and speed-change box, Fig. 6 the shaft motion box at the head of the column, while Figs. 7, 8 and 9 are details of the saddle.

From the section of the column, it will be noticed that the main column casting is stiffened internally by a series of ribs which run through the major part of its height, thus adding greatly to the stiffness of the machine. The weight of the sleeve, &c., is carried by a ball bearing fitted in a recess at the top of the column, while a roller bearing at the top and a plain ground bearing at the base of the column allow the sleeve to swing easily on the column. A bracket fitted in the base of the column carries a bevel wheel as shown. This bevel is keyed to the vertical main motion shaft, and is driven by another bevel on the third motion shaft of the speed-box, and shown in Fig. 5. The diameter of the column is 15 in. and the height allows of a rise and fall of the arm of 3 ft. 2 in.

# 6-FT. HIGH-SPEED RADIAL DRILLING MACHINE.

### CONSTRUCTED BY MESSRS. GEORGE SWIFT AND SONS, LIMITED, ENGINEERS, HALIFAX.

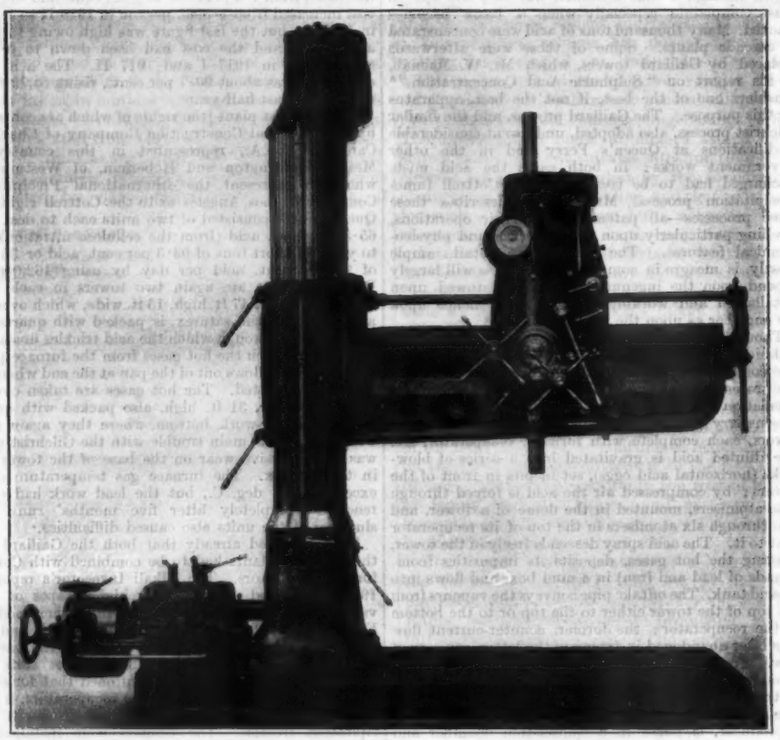
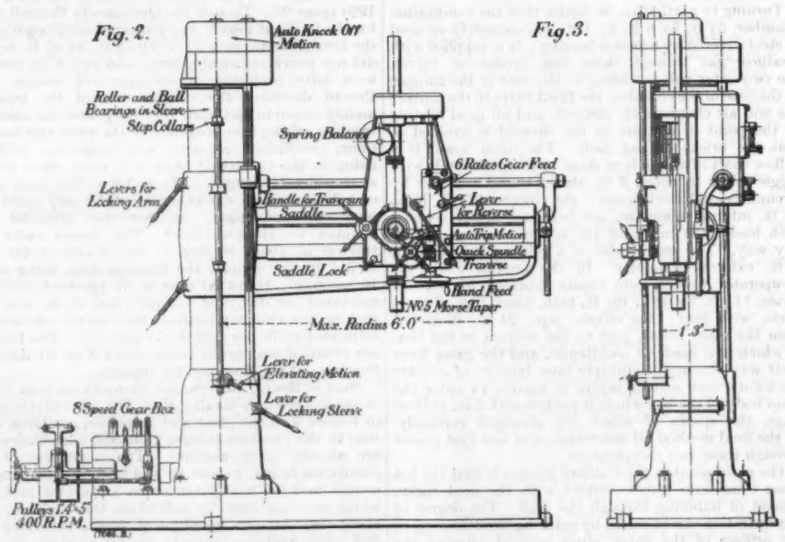


FIG. 1.




The machine as shown is belt-driven by means of fast and loose pulleys, 16 in. in diameter, running at 400 r.p.m. The speed-box illustrated in Fig. 5 gives eight changes, and, with the double gear on the saddle, sixteen speeds in all are obtainable. The box is of the sliding-gear type, sliding gears on the first motion shaft driving sliding gears on the third motion shaft through the second motion shaft gears. The change levers will be identified in Figs. 1 and 2. A short upright lever in front of the box operates the sleeve on the first shaft through the circular rack shown in Fig. 5. Two horizontal levers on the top of the box control the two pairs of gears on the third shaft. Conflicting gears cannot be engaged. The shafts are of high carbon steel, and run in gun-metal bushed bearings. The small hand wheel to the left of the belt pulleys is provided to enable the gears to be inched for gear changing.

The drive is transmitted from the third shaft through the bevels already mentioned to the vertical shaft inside the column. This shaft is denoted by A in Fig. 6. This will be seen to transmit the drive through an intermediate gear to the outside vertical shaft B, which drives the horizontal shaft at the back of the arm and saddle, and from which all drilling and feed motions are derived. The shaft denoted C in Fig. 6 provides the elevating motion of the arm. This screwed shaft will be seen to extend from the head downwards (Fig. 1), and revolves in a nut on the arm. It can be driven in either direction by the gearing shown in Fig. 6, in conjunction with the clutch operated by the lever G. The latter has at its right-hand end a

# 6-FT. HIGH-SPEED RADIAL DRILLING MACHINE.

CONSTRUCTED BY MESSRS. GEORGE SWIFT AND SONS, LIMITED, ENGINEERS, HALIFAX.

*Fig. 4.*

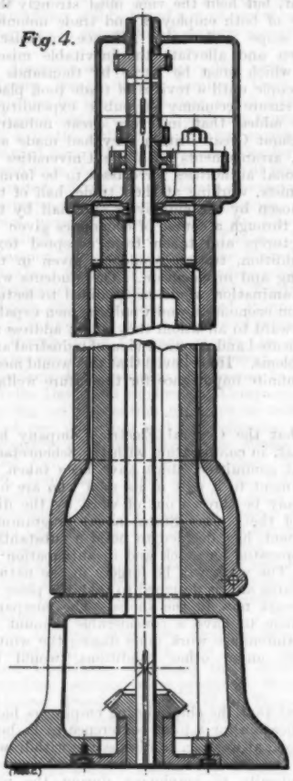


*Fig. 8.*

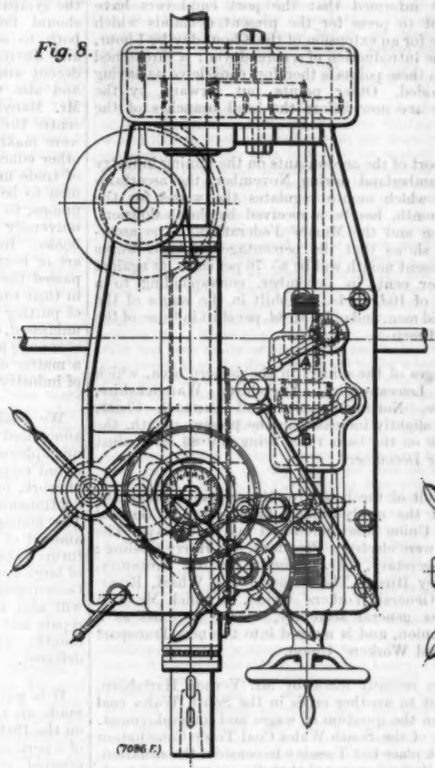


*Fig. 9.*

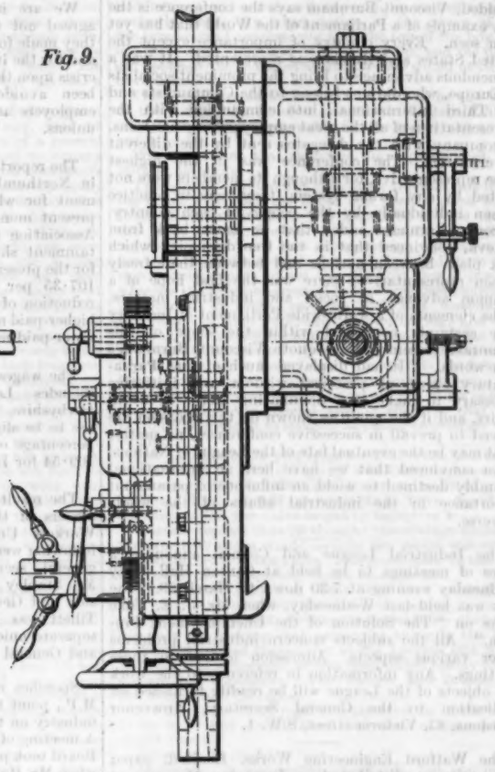


*Fig. 5.*

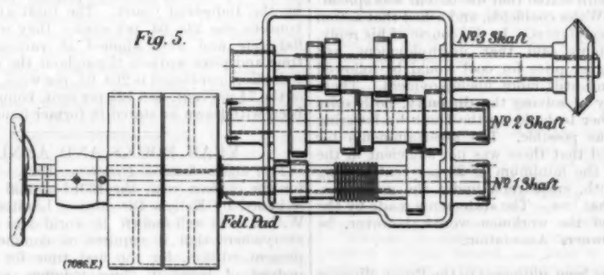



*Fig. 6.* COLUMN BRACKET DRAWN TO SHEW ALL SHAFTS AND GEARING.

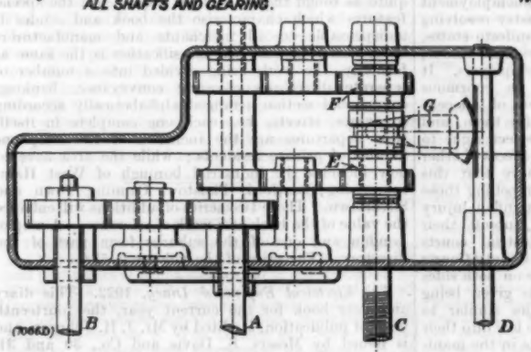
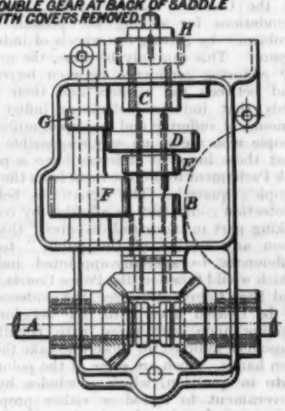



*Fig. 7.* VIEW OF REVERSE MOTION AND DOUBLE GEAR AT BACK OF SADDLE WITH COVERS REMOVED.




quadrant rack which meshes with a rack on the rod D. This rod extends to the lower part of the sleeve, where it ends in another short rack in gear with a pinion fitted with a small hand lever (Fig. 2). The movement of this lever in the up or downward direction causes one or the other of the clutches to engage the gears E and F in the head, thus driving the elevating screw in one sense or the other. The rod D (Fig. 2) will be seen to be fitted with two striking collars, and these are set to throw the clutch out when the arm reaches the limit of its travel. The elevating screw is fitted with ball thrust washers to take the pressure in either direction.

The saddle is illustrated in Figs. 8 and 9, a detail of the reversing motion to the spindle, and the double gearing, being shown in Fig. 7. The spindle is 3¼ in. in diameter and can be fed through 18 in. The maximum height from spindle nose to base is 5 ft. 10 in., and the minimum 1 ft. 2 in. The machine, as already described, provides sixteen speeds in all to the spindle, which has six rates of feed. The drive is through the keyed horizontal shaft above the arm and behind the saddle. This shaft is shown at A in Fig. 7, and will be easily recognised in Figs. 8 and 9. By means of the long lever, slanting down towards the right-hand bottom corner of the saddle (Fig. 9), the clutch shown in Fig. 7 is engaged with one or other of the loose bevels on A, and these drive the spindle C forward or in the reverse direction through the wheel B, which runs with the bevel and is independent of C, the train either B, F and E, or B, F, G and D. The wheels E and D slide on the spindle C and drive it through two keys. These wheels can be moved upwards so that D meshes with G, or down so that E and F are engaged, by means of a small lever at the back of the saddle (Fig. 9). The former combination gives the fast speed and the latter the slow, these being combined, as already described, with eight changes in the speed box. The final drive to the spindle is through gears H, &c., in a casing at the top of the saddle.

The feed shaft, shown to the right of the saddle in Fig. 8, is also driven through a train from H. The six feeds are obtained with sliding gears controlled by the levers A and B (Fig. 8). The lever B gives two main changes to three intermediate gears, and the lever A enables each of these to be combined with gears keyed to the shaft carrying the feed worm. The lever A operates through a small pinion and circular rack to be seen at the upper end of this spindle. The small inverted hand wheel drives the worm direct, for hand feed. For power feed the worm is driven by the spindle just referred to through a clutch engaged by a short lever having at one end a handle and at the other a roller. The latter is struck by a trip on the dial (Fig. 8) on the limit of the desired travel being reached, and declutches the worm. The gearing to the quill of the spindle is seen in Fig. 8. The feed is finally transmitted to the quill by pinion engaging with a rack on the quill. The spindle is carried in the latter by ball thrust bearings at the top and bottom. The normal feeds are 48 to 135 revolutions of spindle per 1 in. feed, and the spindle speeds 20 r.p.m. to 290 r.p.m. A high speed attachment can be added, enabling speeds to be taken up to 870 r.p.m.

The machine is fitted with a base having a working surface of 5 ft. 8 in. by 3 ft. 6 in., and a loose box table can be supplied, measuring 36 in. by 30 in. by 24 in. The weight of the machine is about 7¼ tons.

## INDUSTRIAL NOTES.

DEALING, in the December Journal of the Industrial League and Council, with the International Labour Conference recently held in Geneva over which he presided, Viscount Burnham says the conference is the only example of a Parliament of the World that has yet been seen. Every country of importance except the United States and Russia was represented. It was a tremendous advantage to bring the prominent socialists of Europe, who did not belong to the Communists and the Third International, into communion with the representatives of all the great employers' organisations, in company with the delegates sent by the different Governments. The conference was in the highest sense representative, for although its members were not elected by any formal system, they were in practice chosen individually by the people of each country. Viscount Burnham added that he came back from Geneva, convinced that in the free discussion which took place between nations and between their freely chosen representatives there was the best hope of a common advance in social and industrial matters. "The elements of a world-wide Parliament of Industry were certainly contained within the scope of this memorable assembly," to quote Viscount Burnham's own words. "It had displayed much of that Parliamentary spirit of practical wisdom and initiative necessary to make it a dominating factor in world affairs, and if the qualities shown on this occasion are proved to prevail in successive conferences, no matter what may be the eventual fate of the League of Nations, I am convinced that we have here an international assembly destined to wield an influence of paramount importance in the industrial affairs of the whole universe."

The Industrial League and Council announce a series of meetings to be held at Caxton Hall every Wednesday evening at 7.30 down to March 29. The first was held last Wednesday, when Mr. J. E. Tuke spoke on "The Solution of the Unemployment Problem." All the subjects concern industrial problems under various aspects. Admission is free to these meetings. Any information in reference to the work and objects of the League will be readily furnished on application to the General Secretary, Grosvenor Mansions, 82, Victoria-street, S.W. 1.

The Watford Engineering Works, Limited, paper mill engineers, distributed on December 21, amongst their employees, the amounts earned in the second year's working of the profit-sharing scheme. They state that in spite of the somewhat diminished trade during the year, the distribution worked out at approximately 4½ per cent. on the wages, although the number of workers benefiting had increased by 22·4 per cent. as compared with the previous year. The directors are satisfied that the plan has proved beneficial, and the increased number of workers entering the scheme testifies to the appreciation of the men, both union and non-union.

The supplement published on December 30 by *The Glasgow Herald*, and dealing with shipbuilding, engineering and commerce in the past year, states that within the United Kingdom first place among the shipbuilding areas continued to be held by the Clyde, with the North-East Coast rivers and Belfast following. The production all round was lower, and that of Belfast was lower relatively than that of any other area. The figures given by the journal are the following :—

| | Vessels. | Tons. | I.H.P. |
|---|---|---|---|
| The Clyde .. .. | 249 | 511,185 | 478,760 |
| The Tyne .. .. | 73 | 356,947 | 283,202 |
| The Tees .. .. | 34 | 160,508 | 133,800 |
| The Wear .. .. | 30 | 144,868 | 63,083 |
| The Laggan .. .. | 13 | 93,494 | 70,100 |

The following are the figures quoted for the countries whose shipbuilding output in 1921 was over 200,000 tons :—

| | Vessels. | Tons. | I.H.P. |
|---|---|---|---|
| United Kingdom .. | 804 | 1,506,272 | 1,318,788 |
| United States .. .. | 292 | 1,303,735 | 1,510,894 |
| Germany .. .. | 241 | 622,762 | 369,811 |
| Japan .. .. .. | 119 | 424,284 | 659,185 |
| Holland .. .. .. | 293 | 292,586 | 177,851 |
| France .. .. .. | 119 | 228,974 | 129,135 |
| Italy .. .. .. | 62 | 205,594 | 91,730 |

It is reported that an agreement has been arrived at in the matter of the building trade operatives' wages ; the agreement has been incorporated in a memorandum of the Wages and Conditions Council relating to working conditions. The proposals have been circulated to the branches of the Operatives' Federation for ratification ; the result will be reported to the said council next week. The question of working hours is expected to be settled shortly.

We are informed that the port employers have agreed not to press for the present demands which they made for an extension of the 8-hour day by 1 hour, and for the introduction of a spreadover ; a threatened crisis upon these points is therefore considered as having been avoided. Other points put forward by the employers are now before the local branches of the unions.

The report of the accountants on the mining industry in Northumberland during November, the ascertainment for which month regulates the wages for the present month, has been received by the Coalowners' Association and the Miners' Federation. The ascertainment shows that the percentage on basis wages for the present month will be 85·76 per cent., as against 107·35 per cent, in December, corresponding to a reduction of 10*d.* to 1*s.* per shift in the wages of the higher-paid men, and of 7*d.* to 8*d.* per shift in those of the lower-paid men.

The wages of the miners in the eastern area, which includes Leicestershire, Yorkshire, Warwickshire, Derbyshire, Nottinghamshire and Cannock Chase, are to be slightly increased in the present month, the percentage on the basis rates being 109·86, as against 109·54 for December.

The result of the ballot for the appointment of the officers of the newly-formed Transport and General Workers' Union was announced last Saturday. The following were elected : President, Mr. Harry Gosling ; general secretary, Mr. Ernest Bevin ; treasurer, Mr. Stanley Hirst. The former Dock, Wharf, Riverside and General Workers' Union, of which Mr. Ben Tillett was general secretary, ceases to exist as a separate union, and is merged into the new Transport and General Workers' Union.

Speeches recently made by Mr. Vernon Hartshorn, M.P., point to another crisis in the South Wales coal industry on the question of wages and unemployment. A meeting of the South Wales Coal Trade Conciliation Board took place last Tuesday to consider the situation, when Mr. Hartshorn stated that discontent was spreading in the South Wales coalfields, and asked that action be taken by the employers. In the course of his reply, Mr. Evan Williams said that unemployment had increased ; a higher price for coal would be followed by less trade and still more unemployment. There was but one way of solving the difficulty, both sides combining together to build up the trade by lowering costs as much as possible. The ascertainments for November showed that there was not sufficient in the industry to pay the minimum of 28 per cent. during the present month, employers, under the guarantee, having to bear that loss. The statements made by the representatives of the workmen would, however, be put before the Owners' Association.

A manifesto has been addressed to the Prime Minister by a number of prominent trade unionists and members of the Coalition Labour group, containing recommendations for solving the present unemployment problem "by getting the wheels of industry revolving again." This can only be done, the manifesto states, by restoring confidence between buyers and sellers, and between the workers and their employers. It adds that industrial disputes inflict an enormous amount of suffering and loss upon millions of innocent people who are in no way responsible for them, and that these innocent sufferers have a perfect right to ask Parliament to protect them from the effects of other people's quarrels. The signatories believe that this protection could best be afforded by compelling those taking part in industrial disputes "that inflict injury upon any section of the public" to submit their differences to specially-appointed industrial courts which would function like Police Courts, County Courts and High Courts of Justice, the evidence on both sides to be treated upon oath, the decisions given being binding upon both sides, with penalties similar to those now inflicted for those who take the law into their own hands. Such are some of the points in the manifesto in question, which concludes by urging upon Government to introduce either proposals of their own, or else to give facilities for the Industrial Armistice Bill which was introduced at the end of the last session of Parliament.

Mr. E. Manville, M.P., joint chairman of the National Alliance of Employers and Employed, is reported to have stated, in the course of an interview last Monday with a press representative, that the views of the Alliance with regard to unemployment were that it should throw itself into the breach as far as its resources would allow, and that it had a direct responsibility to fulfil. The Alliance did not, and could not wish to interfere with governmental responsibilities for dealing with unemployment, but held the view most strongly that the sympathy of both employers and trade unionists should find scope under the Alliance organisers, both to soften and alleviate the inevitable misery and distress which must be borne by thousands of decent workpeople until a revival of trade took place, and also to ensure economy of public expenditure. Mr. Manville added that in every great industrial centre throughout Great Britain they had made and were making, arrangements with the Universities or other educational authorities for classes to be formed of trade unionists, working at their trade, half of the men to be chosen by the employers and half by the unions, to go through a course of economics given by university lecturers and taken from accepted text-books. In addition, tuition would be given in the art of lecturing and in elocution. The students who passed the examination would be qualified to lecture in their turn on economics, and would be men capable of putting forward to all whom they might address an unbiassed, educated and practical view of industrial and economic problems. He believed that this would mean a matter of infinite importance for the future welfare of industry.

We read that the General Electric Company has announced that, in co-operation with the Schenectady unemployment committee, steps have been taken to afford employment to a part of its men who are out of work, or may be thrown out of work by the discontinuance of the United States naval programme. The management has decided to build a substantial amount of apparatus for stock and in anticipation of future sales. The work will be largely in the nature of large apparatus and is designed to take the place of Government work now in the shops. The company will also arrange to have a considerable amount of repair and maintenance work done during the winter months which, under other conditions, would be deferred.

It is reported that the shipbuilding employers have made an application for a joint conference to be held on the 19th inst., at Carlisle, to discuss the withdrawal of a portion of the "cost of living" bonuses which were granted periodically to employees during the war by the Industrial Court. The total amount of such bonuses was 33*s.* 6*d.* per week ; they were made on a flat rate and were applied at various intervals to time and piece workers throughout the industry. The reduction mentioned is 26*s.* 6*d.* per week, independently of the 7½ per cent. and 12½ per cent. bonuses which have been withdrawn as stated in former issues.

## YEAR BOOKS AND ANNUALS.

*Post Office London Directory*, 1922.—This directory for the current year, the 123rd annual edition, which is issued by Kelly's Directories, Limited, 186, Strand, W.C. 2, is so well known the world over and so popular everywhere that it requires no commendation. The present edition, for the first time for several years, instead of being in three volumes, appears in one volume only, including the county suburbs portion, a departure which will be welcome. It is printed on quite as tough though thinner paper. All the special features which characterise the book and render it indispensable to all merchants and manufacturers have been retained ; the classification is the same as formerly, the work being divided into a number of separate directories covering conveyance, banking, commercial section arranged alphabetically according to names, streets, &c., each one complete in itself. New departures are the inclusion of the telephone number of private residents ; while the area covered now includes the industrial borough of West Ham, comprising Stratford, Plaistow, Canning Town and Silvertown. These two series of additions will enhance the value of the book as a work of reference. A map of London and one of the suburbs form part of the directory. The price of the volume is 55*s.*

*The Electrical Engineers' Diary*, 1922.—This diary and year book for the current year, the fourteenth year of publication, is edited by Mr. J. H. Johnson, and is issued by Messrs. S. Davis and Co., 30 and 31, St. Swithin's-lane, E.C. 4. It appeals to a wide circle of engineers, contractors, architects and to all users of electrical apparatus. The information it contains covers the generation of electricity from the boiler-house down to the utilisation of the current. All classes of machinery driven by electricity, or to which electricity is applied for any given purpose, are reviewed in detail. Special chapters deal with the application of electricity to lighting, the installation of telephones and bells, electric cooking, heating and cleaning, wiring rules, &c. Technical terms and

definitions are explained, and tables are given containing the various electricity supply stations in the United Kingdom. The diary portion is at the end of the book. The price is 10*s.* 6*d.*, or 11*s.* 6*d.*, post free. This publication will be found a most useful one for reference purposes in regard to all matters electrical.

*Almanacs and Calendars.*—We have received from Messrs. Henry Simon, Limited, their daily tear-off calendar for the current year, which is in the style they adopted many years ago, each day reproducing a verse or a motto written by a large variety of wise and learned men. A daily tear-off calendar also comes to hand from the Keighley Gas and Oil Engine Company, Limited, affixed to a cardboard elevation of one of their Imperial internal-combustion engines. Similar calendars have also been issued by Commercial Cars, Limited ("Commer Cars"), Luton; Messrs. H. R. Marsden, Limited, makers of the Blake-Marsden stone-breaker, Soho Foundry, Meadow-road, Leeds; The Davenport Engineering Co., Ltd., Bradford and Hull; Messrs. Shaw and Sons, Limited, Printers, Fetter-lane, E.C. 4, have sent us their improved tablet diary, having a thumb index for each month, by which forward dates can be turned up in a moment. A refill of cards for their desk calendar also comes to hand from the Welin Davit and Engineering Company, Limited, each giving an illustration of shops or tackle, the week, and two preceding and two following months; also a monthly desk calendar from Messrs. J. Evershed and Co., printers, Fairfield Road, Bow, E. 3, and 86, Long Lane, West Smithfield, E.C. 1.—We have received monthly wall calendars, some of them highly decorative, from the following firms: Messrs. Abdulla and Co., Limited, 173, New Bond-street, London, W.; Messrs. Brown Brothers, Limited, motor, aircraft, cycle and tool manufacturers and merchants, 20 to 34, Great Eastern-street, E.C. 2; Messrs. W. Ottway and Co., Limited, scientific instrument manufacturers, Orion Works, Ealing, London, W.; Messrs. Aiton and Co., Limited, engineers, Derby; Messrs. Sir W. G. Armstrong, Whitworth and Co., Limited, Elswick and Openshaw, depicting their ships, locomotives, machine tools and other products; Messrs. Mawdsley's Limited, Dursley; Messrs. H. O. Thompson, Limited, engineering contractors, Devon House, 4, Upper Bedford-place, W.C. 1; Messrs. Cammell Laird and Co., Limited, showing their Birkenhead shipbuilding yard and works; Messrs. Rd. Johnson, Clapham and Morris, Limited, general hardware factors, &c., 24 and 25, Lever-street, Manchester; Messrs. Hulse and Co., Limited, machine tool makers, Ordsal Works, Manchester; Messrs. Royce, Limited, manufacturers of lifting and hauling machinery, Trafford Park, Manchester; Messrs. Peckett and Sons, Limited, locomotive builders, Bristol; Mr. Harrison Ainsworth, photo-printer, 197, The Grove, Hammersmith, London, W. 2; Messrs. R. Y. Pickering and Co., Limited, railway rolling-stock builders, Wishaw; Messrs. The Glacier Metal Company, Limited, Waldo-road, Willesden Junction, N.W. 10; Messrs. Averys, Ltd., 6 and 7, Stonecutter Street, Ludgate Circus, E.C. 4; Messrs. Geo. Cradock and Co., Ltd., Wakefield; The Churchill Machine Tool Co., Ltd., Broadheath, Manchester; The International Construction Co., Ltd., 56, Kingsway, W.C. 2; Messrs. Heatly and Gresham, engineers, Calcutta, Madras, London, Bombay and Lahore; Messrs. R. and H. Green and Silley Weir, Ltd., ship and engine repairers, Blackwall, E. 14; Messrs. J. C. Fish, Hall and Co., stationers and printers, 11, Bishop's Court, Chancery Lane, W.C. 2; Messrs. Harrison and Sons, Ltd., printers, London and Hayes. Also a weekly tear-off calendar from the National Gas Engine Company, Limited, Ashton-under-Lyne.—We have received from Mr George Ellison, switch gear manufacturer, of Perry Barr, Birmingham, a very attractive picture of a young lady against a background which might represent the Black Country at its worst.

## THE LOCOMOTIVE BOILER EXPLOSION AT BUXTON.

THE explosion of the locomotive boiler on the London and North-Western Railway, at Buxton, on November 11, and particulars of which were given in ENGINEERING for December 2, page 759, has been the subject of the adjourned inquest which was conducted by Mr. Sydney Taylor, the coroner for the division, at Buxton Town Hall on December 9. The London and North-Western Railway Company were represented by Captain H. M. Beames, chief mechanical engineer; Mr. G. A. Dimley, assistant running superintendent; Mr. Denning, assistant works manager; and Mr. S. Stoker, assistant traffic superintendent. Messrs. Beardmore, who had made recent repairs to the engine, were represented by Messrs. Blacklock and Fawcett; and Mr. Brassington and Mr. Reinmer appeared for the National Union of Railwaymen.

The coroner stated that the deceased men, into the cause of whose death the jury were met to inquire, were William Holme, engine driver, of Springhead, Oldham, and Walter Fletcher, fireman, of Oldham, both of whom were instantaneously killed when the explosion occurred. He had had certain correspondence with various people since the jury had last met, and he thought the time had now come to clear the matter up so far as was possible, but he was afraid they would not be able to get very much further.

The first witness called was R. Winstanley, engine driver, who had brought the ill-fated engine to Buxton. At the last inquiry he stated that the steam gauge had registered a pressure of 300 lb. on the square inch, and he now, in reply to the coroner, stated that when he brought the engine to Buxton the night before the explosion he did not travel at an unusual rate, but had a light train.

Captain Beames, of Crewe, chief mechanical engineer of the London and North-Western Railway, said he would like to give his evidence in the form of a general statement. In the first instance, he wished to convey to the relatives of the deceased his own and his company's sympathy with them in their great loss, his own especially because their deaths were due to the explosion of a boiler which came to a large extent under his maintenance. The various parts of the engine which exploded had been removed to the Crewe works and carefully examined. The boiler in question was sixteen years old and in excellent condition, and had been repaired in 1921. So far as could be seen the repairs both to the boiler and engine were carried out efficiently. The boiler had been maintained in perfect condition throughout its life. Since the explosion a most careful examination had been made, at the works, and he had come to the conclusion that the first part of the boiler which fractured was the crown of the fire-box. This was clearly shown by certain markings on the back of the fire hole, showing that the back plate was in position when the crown plate came down, and they had to look for the cause of that particular plate coming down. The only thing which had been found fractured were two roofing bar links, as they called them, on the left hand side at the back of the boiler. Some of the roofing bar pins were bent and others were sheared through. Tests which had been made of important parts showed that the material was excellent and more than conformed to the British Standard specification. That led them to assume what would be the condition taking it for granted the crown of the fire-box had collapsed. The tests carried out from material parts showed tensile strengths of 37 and 38 tons per square inch.

Assuming that the boiler contained 4½ tons of water, which would take 2 hours to raise to a temperature corresponding to a steam pressure of 150 lb. per square inch, it would have stored up in that boiler what, if it had been allowed to escape in 2 hours, would mean about 1,980,000,000 ft.-lb. of energy. If they assumed that amount was allowed to escape in a fraction of a second the result would be very much the same as a violent explosion. Therefore, he (witness) assumed that there had been a very excessive pressure in the boiler. This was borne out by the results; the fire-box was blown out in four different directions, which was quite consistent with that theory. That brought them to the next point and led them to ask what was the cause of the roof of the box collapsing.

The Coroner: So far as you have gone, do we draw the inference that the cause of the explosion was the top of the box collapsing? You do not apparently suggest anything but that?

The witness, in reply, said that they found markings on the plates which convinced him and his colleagues that the top of the fire-box was the first part to go. Had it been the back of the boiler or the front they would not have found the markings they did. As he had previously stated, they found the material excellent, though there were certainly two roofing bar links broken.

Witness proceeded to say that as a matter of satisfaction he had carried out tests to destruction of an engine, similar to the one which exploded, but two years older. They obtained an hydraulic test pressure up to 600 lb. per square inch on the boiler, when one of the roofing-bar bolts was found to be partially fractured. This let the pressure out, thus finishing the test. The fire-box was in a most excellent condition still, but the crown had sagged down slightly, owing to the great pressure, and that again led them to assume that there was a very excessive pressure in the boiler which had exploded.

The evidence given before the coroner and the Ministry of Transport officials pointed to the fact that the steam gauge was reported to be registering 300 lb. per square inch, prior to the accident. The gauge had been tested in his presence and the presence of the Ministry of Transport officials, and was found to be practically correct, or within a matter of 10 lb. either way, which was quite immaterial.

They had had evidence put before them to the effect that up to a certain date the safety valves of the exploded boiler had blown freely and consistently. That was up to either September or October. Subsequent to that date it did not seem, so far as the evidence went, that the safety valve had been known to blow-off. They, therefore, carried out tests on the safety valve, or what remained of the safety valve of the engine, with a view to satisfying themselves whether the valve had stuck or not. There were two wing valves, and one was blown out, and the lever bent right round. The other was in place, the lever and spring being intact. They had carried out several examinations and tests but had not found any evidence—conclusive evidence—to show that that valve was stuck at the time of the explosion. He said that because the front wing valve was free when examined. Of course, it must be remembered the lever was quite bent. With regard to the safety valve not working satisfactorily, witness said it was a most unusual occurrence. They had 3,400 engines on the London and North-Western Railway, each of which was fitted with two of those valves, and they could not find in the history of any man in the employ of the company evidence of the lever of a safety valve sticking. That was a defect that had been known to take place elsewhere, but not on the London and North-Western Railway. His own impression was that it was a defect in the safety valve that was the cause of the accident. There was one thing he had left out and which, witness said, he wanted to make perfectly clear. An examination of the crown of the fire-box showed conclusively that the top of the box had not been dry. The lead plug was intact, and the plates did not show the scorched condition they would otherwise have done.

The coroner remarked that it seemed to be the belief on the part of the London and North-Western Railway officials that it was impossible for the safety valve to be out of order.

Witness replied that that was the impression on that railway certainly.

The coroner pointed out that other theories put before the court were that the boiler had been allowed to get short of water, but that was negatived by the fact of the state of the fire-box crown. Another possibility mentioned had been that some foreign substance had got into the fire-box with the coal, but had there been, they would expect to see the fire-box blown upwards, whereas the point of greatest failure was downwards.

Witness, in reply, said he had had considerable experience of high explosives before, during, and since the war, and he always found that they struck the point of greatest resistance. Had it been on the bed of the fire it must have been forced downwards, and had it been anything in the nature of dynamite, glycerin, gun-cotton, or any other "ites," he would not in his opinion, expect to find the general soaring effect in that case. It would be difficult to imagine anything to produce those results.

The Coroner: Do you consider that when the engine was brought in, and the gauge was found to have registered up to 300 lb.; that the driver or the fitter, or the foreman fitter, should at that stage have drawn the conclusion that the valve might be defective?

Witness replied that he thought the average driver on the North-Western would assume the gauge was wrong, and would trust to the valve. The entry made in the book was what, in his opinion, could be expected.

The coroner said that what they had to decide in this case was whether the different people concerned acted reasonably, and whether the driver fairly discharged his duty by making that particular entry in the book.

Witness replied that so far as the London and North-Western was concerned he was responsible purely for the mechanical appliances. The drivers and firemen did not come under his ruling.

A Juryman: With regard to the sticking of the valve. If the valve had already stuck, the effect of the explosion might free it?

Witness: It might.

Juryman: It was tested afterwards, but you cannot rely on that for everything.

Witness: Quite so.

Juryman: How can the engine driver try the valve?

Witness: Outside the cab, by moving his lever.

Captain Beames said that the Ministry of Transport and himself had not agreed upon the cause of the safety valve sticking.

A Juryman: You would not like to express an opinion as to the cause of the valve sticking?

Captain Beames: It would not be fair to give an opinion.

This concluded the taking of evidence. The coroner in summing up said he thought that was all the evidence they could have in the case, and on that evidence the jury must give the best verdict they could. Of course, he reminded them, they were not sitting there with any idea that they were expert engineers, but to give a simple answer to a simple question. That was whether the deaths, respecting which they were inquiring, had occurred as the result of what was commonly called an accident—that was an event which could not reasonably have been prevented by the exercise of ordinary care—or whether it was due to neglect by some persons who had a manifest duty to perform. They had got that much further since the adjournment, whereas if they had given a verdict the last time, the matter would still have been in doubt as to which one of the three possible causes put forward by Mr. Dingley was the correct one. They were now driven back to the conclusion that why the gauge was showing too much pressure was that the valve was not acting in a satisfactory manner, but the exact cause they did not know. What caused the valve to stick had not yet been agreed upon, but they had to ask themselves, was anyone to blame for a manifest neglect of duty? It had been said that on the North-Western a case of a valve going out of order had never been known amongst the higher or lower ranks. The valve was looked upon as a kind of bible, and could not possibly go wrong. That left the impression that the men concerned could not be expected to do more than they did. Had they done everything that was reasonable, or ought they to have satisfied themselves that the valve was out of order? That was the point he orginally felt a doubt about.

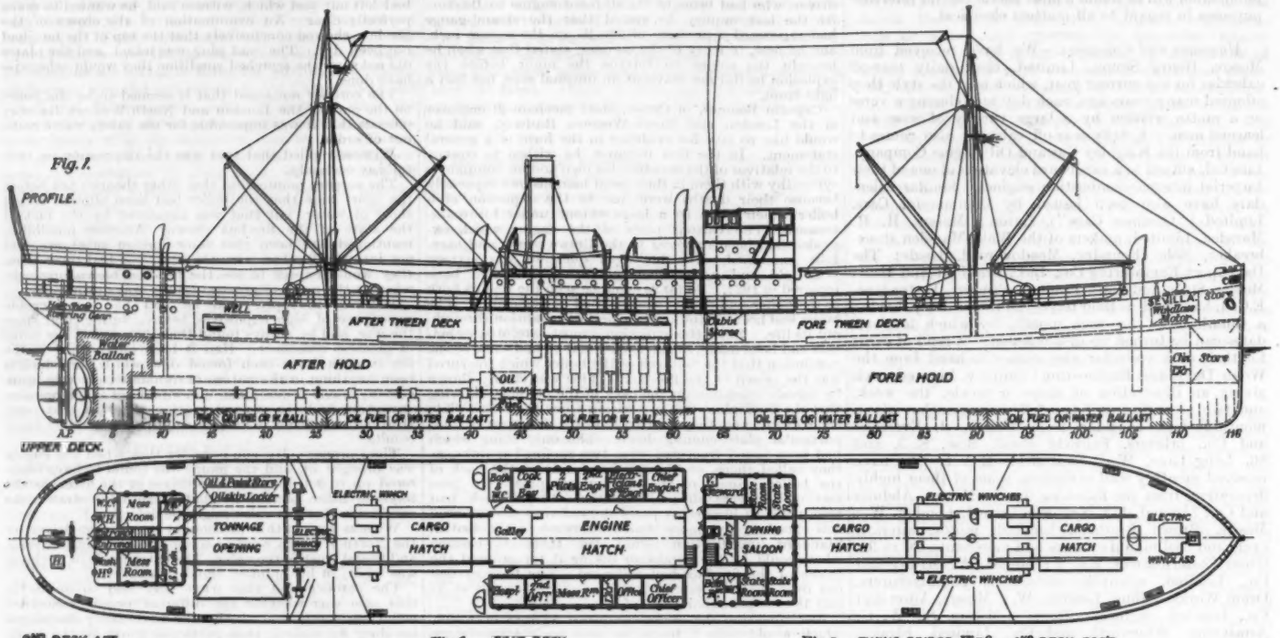
The jury retired to consider their verdict and were absent about half an hour. On their return the foreman Alderman Cooper, said:—

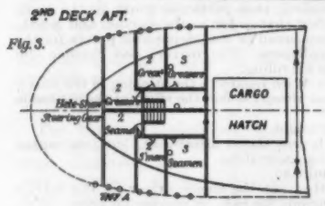
"The jury are all agreed. The conclusion we have come to is that these men met with their deaths through the accidental bursting of a locomotive boiler.

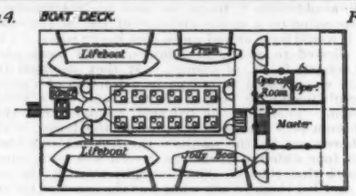
"The jury recommend that a stopcock should be placed on the steam pipe under the gauge to enable the fitter to shut off steam whilst replacing the gauge, and enable him to test the new gauge under the same pressure. The jury is of opinion that more care might have been taken to see that it really was the fault of the gauge before the engine was sent out the second time." An expression of sympathy with the bereaved relatives was made on behalf of the jurymen by the foreman.

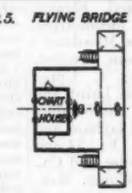
# THE MOTOR SHIP "SEVILLA."

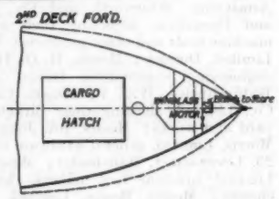
CONSTRUCTED BY MESSRS. WOOD, SKINNER AND CO., SHIPBUILDERS, NEWCASTLE-ON-TYNE.




THE motor ship Sevilla, which we illustrate on this page, pages 13 and 16, and Plate I with our issue this week, is a steel screw motor vessel built by Messrs. Wood, Skinner & Co., Bill Quay, Newcastle-on-Tyne, to the order of Messrs. Dampskibsaktieselskabet Otto Thoresen's, Linie, of Christiania, Norway. The principal dimensions of the vessel are length 270 ft., breadth 37 ft. 8 in., depth to combined bridge deck 25 ft. 6 in., and she is capable of carrying over 2,000 tons deadweight on a moderate draft of water. The vessel, shown in Figs. 1 to 6 above, and Fig. 22, page 16, is of the single-deck class, with a combined poop, bridge and topgallant forecastle. As shown in Fig. 3, a steel deckhouse is arranged amidships containing saloon, staterooms, steward's room, pantry, bathroom, &c. An inside stair leads to a steel house on the upper bridge. This contains captain's room, wireless room and operator's cabin (Fig. 4). A chart-house is fitted on the flying bridge (Fig. 5). Accommodation for the officers and engineers, mess-room, bathroom, hospital, &c., is arranged on the deckhouse on either side of the machinery casing (Fig. 3). The quarters for the crew are in the poop, with steel entrance house overhead, containing mess room, wash-houses, &c., as will be seen in Figs. 2 and 3. The vessel is specially intended for the fruit carrying trade, and is fitted with four hatches, and the provision made for the handling of cargo includes double steel tubular derricks to each hatch and seven electric winches. A Hele-Shaw Martineau electro-hydraulic steering gear with telemotor control, and an electric windlass, are also fitted. The cellular double bottom is arranged to carry oil fuel throughout, and a special reserve tank is also fitted as required by the Norwegian authorities. The Sevilla is rigged as a two-masted fore-and-aft schooner, and is of quite a handsome and yachtlike appearance. The vessel has been constructed under the special survey of Det Norske Veritas and also to the requirements of the Norwegian law.

The main engines, which were built by the North-Eastern Marine Engineering Company, Limited, of Wallsend-on-Tyne, are of the Werkspoor design, of the four cycle, single-acting marine type, with crossheads and guides, having six cylinders each of 560 mm. bore by 1,000 mm. stroke (about 22 in. by 39 in.). At 120 r.p.m. they develop 1,400 i.h.p. Sections of the vessel showing the machinery arrangements are given in Figs. 11 to 14, Plate I, while the engines are shown in Figs. 8 to 10, and also in the reproduction of the photograph, Fig. 21, page 16. The oil fuel for the engine is pumped from the double bottom to a settling tank adjacent to the engine room. From this tank it is transferred as required to a fuel filter, Figs. 12 and 14, placed so that the oil gravitates to the high-pressure fuel pump. Forced lubrication is used to all the main bearings and the reciprocating parts.

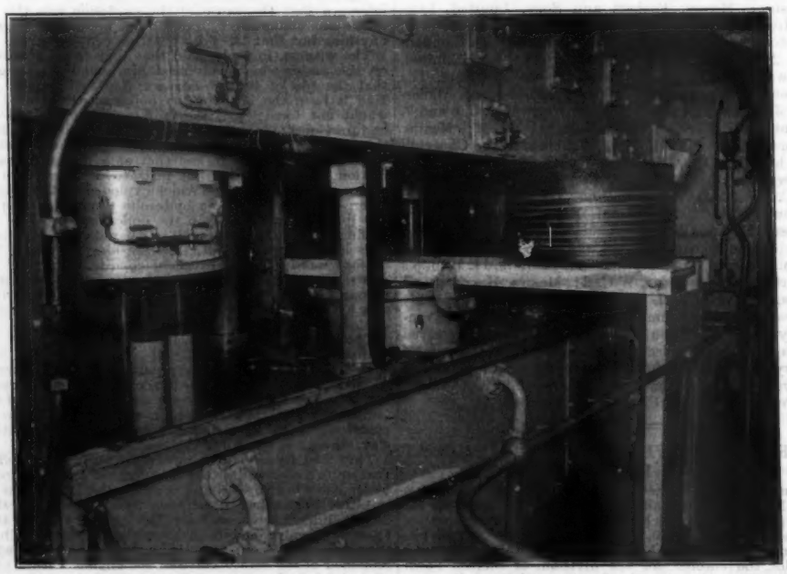


FIG. 7. PISTON BEING REMOVED FROM ONE OF THE CYLINDERS.

The engines will be seen to be entirely enclosed with portable casings. An interesting point is that the cylinder liners and heads are cast in one piece, Fig. 8, and are inserted in cast-iron casings, which form the water jackets. There are two such casings which each take three cylinders, the two being bolted together in the middle. The water jackets have a number of openings, fitted with covers, to permit easy inspection and cleaning. To allow an ample flow of cooling

# 1,400 I.H.P. WERKSPOOR DIESEL ENGINE

CONSTRUCTED BY THE NORTH-EASTERN MARINE ENGINEERING

(For Description, see P

*Fig. 8.*

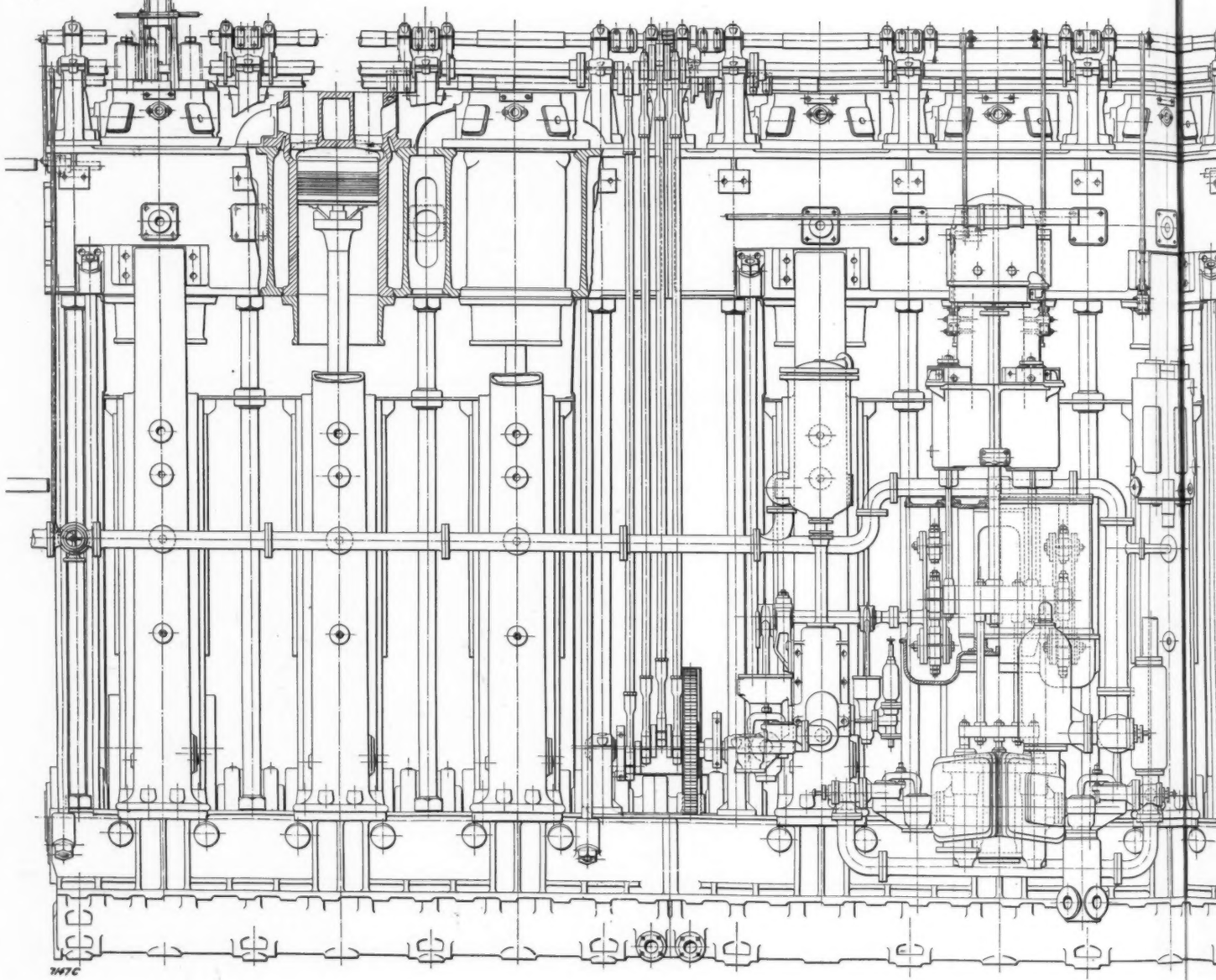



*Fig. 11.* SECTION AT FRAME 46 LOOKING AFT.

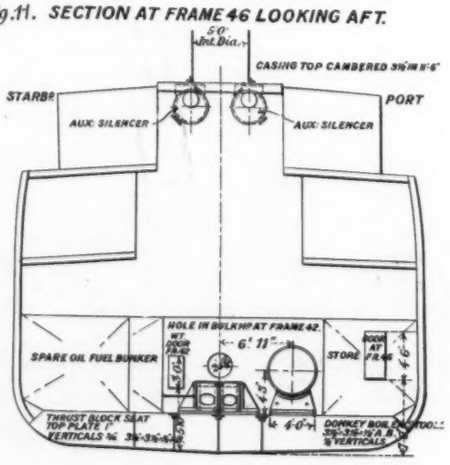
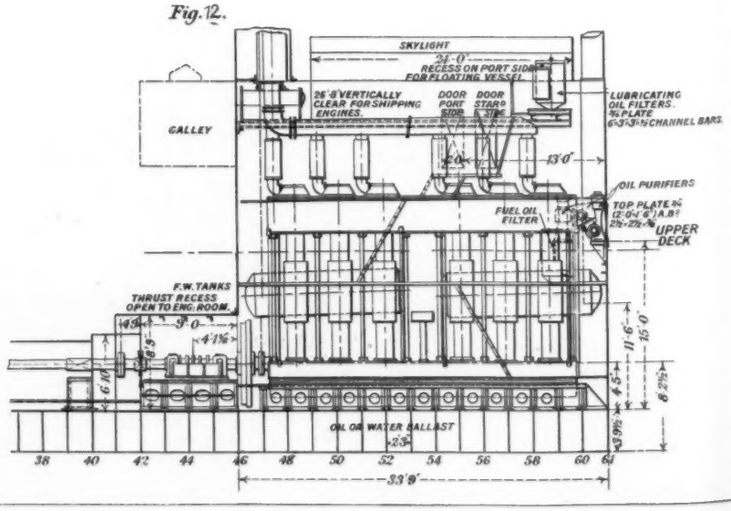



*Fig. 12.*

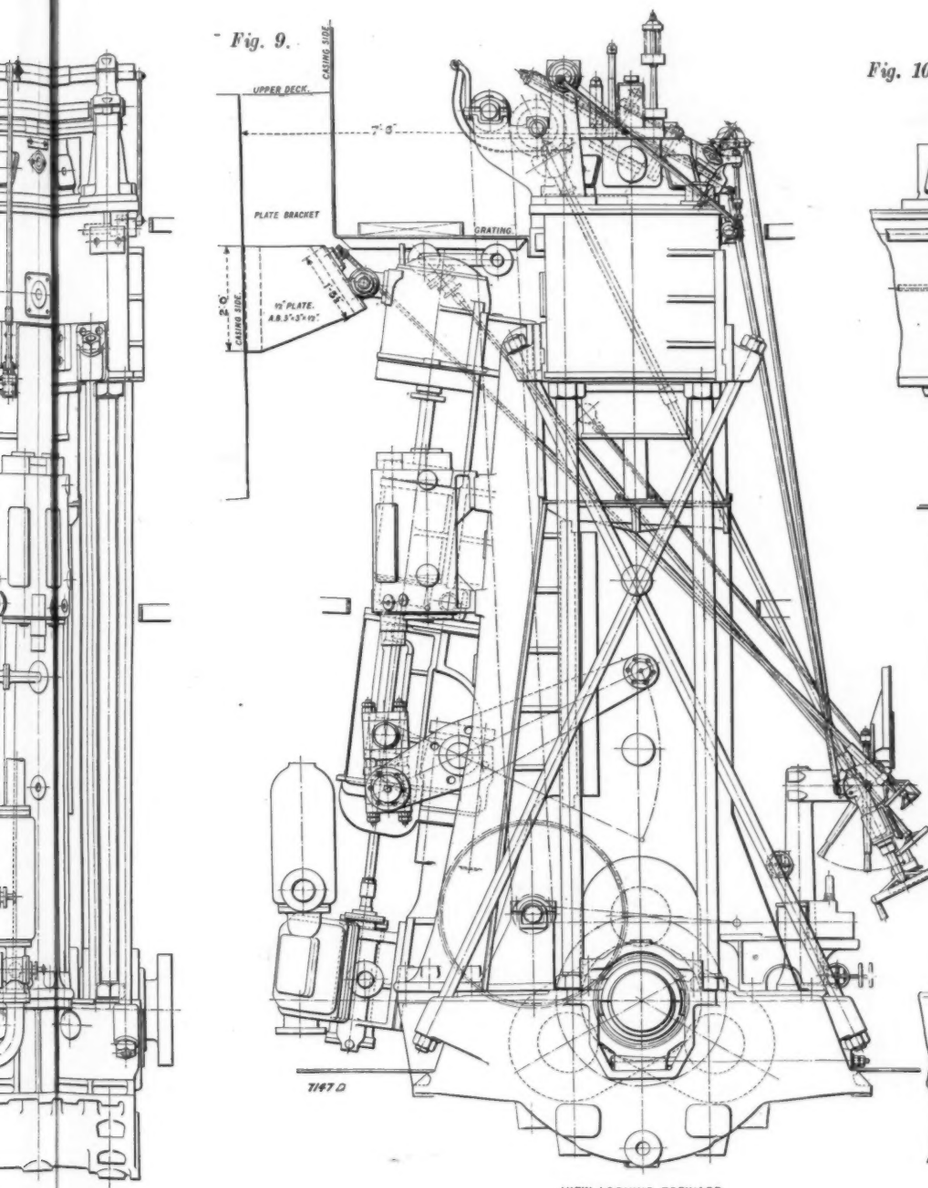


# NGINE FOR THE MOTOR SHIP "SEVILLA."

ENGINEERING COMPANY, LIMITED, ENGINEERS, WALLSEND-ON-TYNE.

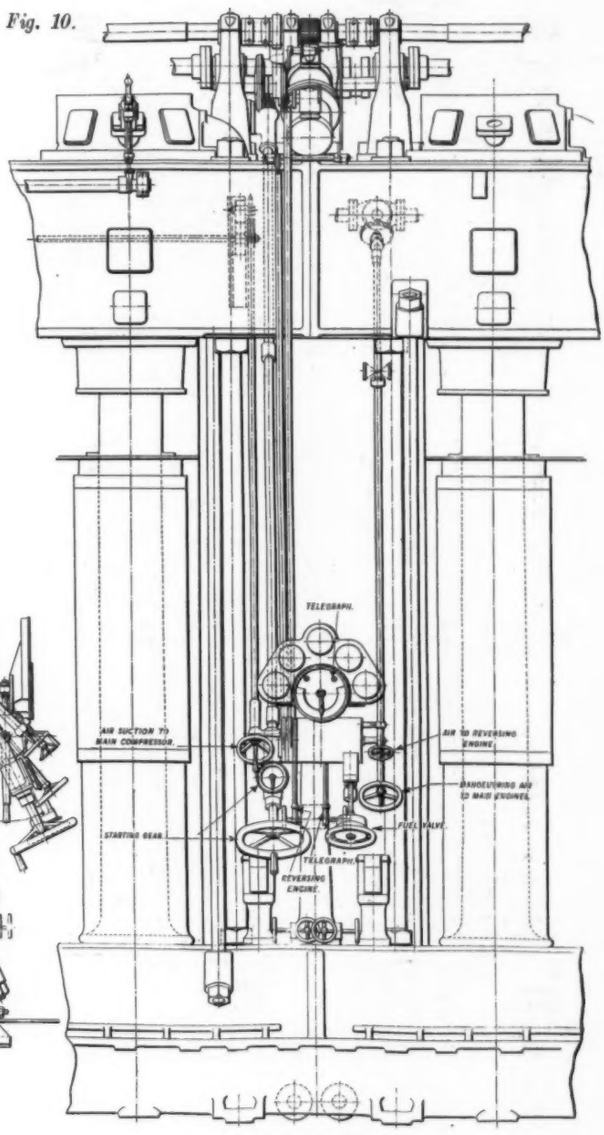
(Description see Page 12.)

*Fig. 9.*




VIEW LOOKING FORWARD.

*Fig. 10.*




FRONT VIEW.

*Fig. 13.*

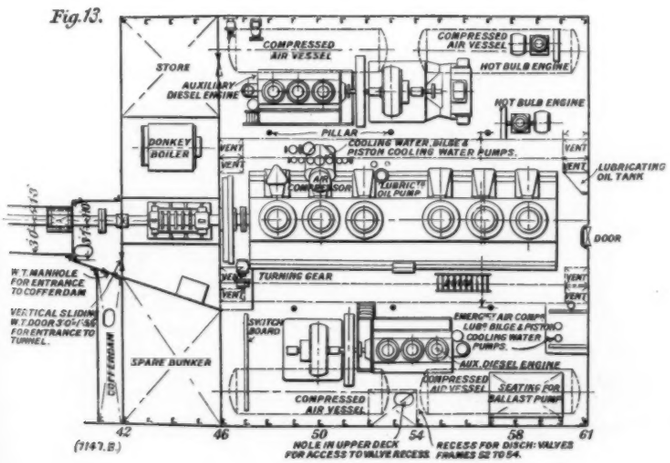
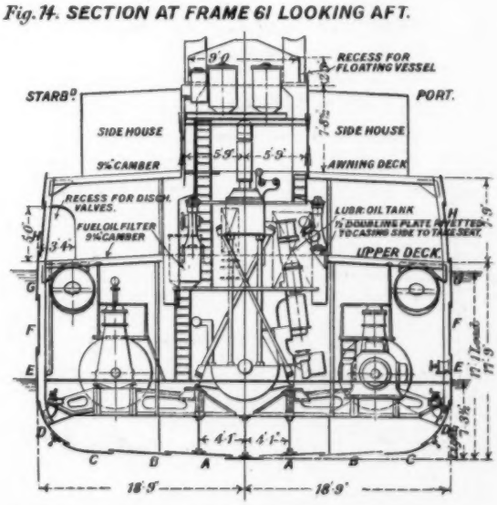



*Fig. 14.* **SECTION AT FRAME 61 LOOKING AFT.**



water round all valves, the fuel valve is placed slightly out of the centre in the cylinder head. This does not affect correct combustion in any way.

An important feature is that all the hottest parts of the cylinder walls and crown are effectively cooled, this being much more feasible in this design than when the cover is separate. Each cylinder has one air inlet and one exhaust valve, one fuel-injecting needle valve, and one air starting valve. All the valves are placed in cages which can be easily dismounted; the outlet valve cage is water cooled, and all valve springs are on the outside, well removed from the high temperatures, and open to view. Further, each cylinder is provided with a relief valve which is opened when the engine is reversed or stopped, and also serves the purpose of a safety valve.

the outside of the bedplate (Fig. 9). The bottom of the bedplate is cast solid, forming a sump for the collection of lubricating oil escaping from the bearings. The top of the crank-case is closed by a steel plate to which cast-iron trays are fixed. These trays serve as a support for the telescopic piston cooling water pipes, and also to collect and drain away any water or oil escaping. Sea water is used for cooling the pistons and cylinder jackets; the overflow from the former is led to inspection troughs, from which it flows to one of the bilge pumps to be discharged overboard. The exhaust valves receive their cooling water through a connection from the cylinder jackets, and the discharge is led to a cooling-water inspection trough, whence it flows overboard.

The lowest portion of the cylinder barrel is detachable. The piston descends into this extension piece when its crank is on the bottom dead centre, so that when the extension piece is lowered the piston is entirely exposed and may be drawn out horizontally. By this device much work is saved; to inspect and replace all the pistons of a six-cylinder engine takes less than one working day. Fig. 7, page 12, shows a view with this extension for one cylinder lowered out and the piston withdrawn for inspection.

AIR INLET & EXHAUST VALVE LEVERS IN AHEAD-NEUTRAL & ASTERN POSITIONS.

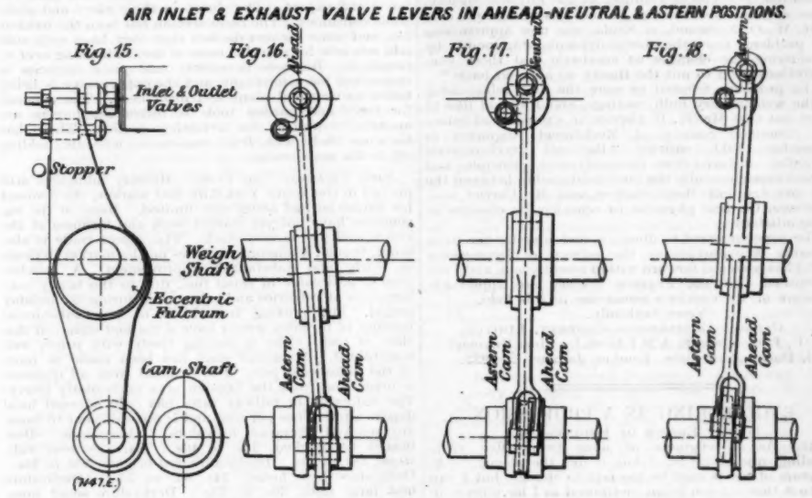



Fig. 19. FUEL OIL CONTROLLING & DISTRIBUTING SYSTEM.

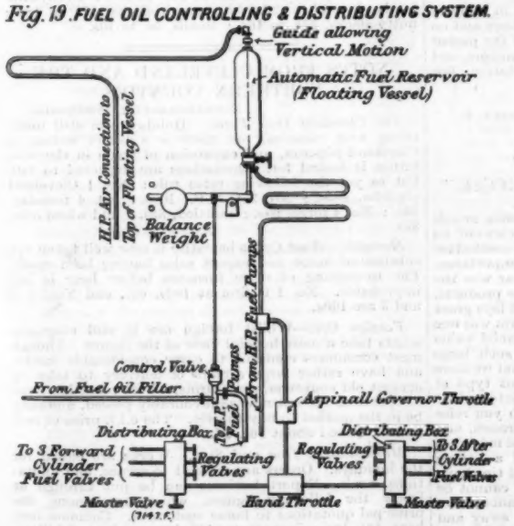
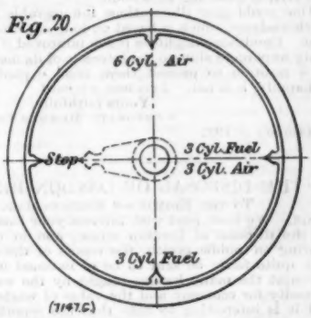



Fig. 20.




To take up the lateral thrust of the crossheads, cast-iron columns with ahead and astern way guides are placed at the back of the engine, the ahead guides being water-cooled. The columns, which are well shown in Fig. 9, are bolted to the bedplate, but at the top there is no rigid connection to the cylinder casing. Guide strips prevent horizontal motion, but some play in the vertical direction is possible. The only support between cylinders and bedplate is by means of vertical steel columns, which pass from the underside of bedplate to the top of cylinder casing. This construction takes in a most direct manner the vertical forces produced in the cylinder. To ensure stability and prevent vibration across the engine, diagonal stays connect the cylinder casing to the bedplate. The rigidity of this construction was well demonstrated on the trial trip, which took place in a heavy sea, the ship being light. The general lines of the design, with steel columns and diagonals, makes a very accessible engine, and considerably reduces the weight. These features will be clearly followed in our illustrations.

In order to facilitate adjustment of the main bearings, the bottom half is carried on a wedge adjustable from

The valve gear is of very simple design, only one camshaft being used on which the ahead and astern cams are mounted. There are two cams for each of the air inlet, exhaust and starting valves, and the lever rollers take up their position over either set of cams as required. As may be seen by reference to Figs. 15 to 18, these levers are mounted on a weigh shaft, and the fulcrums are eccentrics. The axis of the eccentrics and the shaft on which they are mounted are not parallel, so that when the shaft is rotated through an angle of 180 deg., the rollers are lifted from one set of cams and placed upon the other. The gear for operating the fuel valve has only one cam, the roller being moved to a different position in the same plane by the action of the reversing gear. The half-time shaft is driven from the main crankshaft by spur gearing and drives the camshaft by means of long coupling rods; this gear is located in the middle of the engine (Fig. 8). The cranks of these coupling rods are set at angles of 90 deg., and half brasses are fitted on the upper ends only, so that these rods are never in compression, but only in tension. With this construction, repairs and overhauling may be executed, and without disturbing the valve timing in either ahead or astern gear. Reversing is effected by a servo-motor (Figs. 9 and 10), consisting of an air cylinder and oil cylinder, controlled by a lever at the starting position (Fig. 10). This lever is interlocked on the Hunter and Mackay system with the engine-room telegraph in such a way that if the correct reply has been given to the order received from the bridge, it is impossible to start the engine in the wrong direction.

Referring to the indicator on the starting gear, Fig. 20 (which is also to be seen to the left of the centre on the front of the main engines, Figs. 10 and 21), one turn of the starting hand wheel puts all six cylinders on air; a further turn places three on fuel, the other three remaining on air; another turn places all six cylinders on fuel, and a fourth brings the gear back to stop position. It only takes a few seconds to start or reverse the engines.

The Werkspoor system of oil fuel feed is adopted. This is illustrated in Fig. 19, the oil being fed to the cylinder fuel valves by gravity from a floating vessel which is balanced by a counter-weight. The fuel is pumped into this vessel by a high pressure fuel pump, and as soon as the amount of fuel exceeds a certain weight, the floating vessel tips the balance, and by this movement shuts off the fuel supply to the high-pressure fuel pump. To balance the injection air pressure in the cylinder fuel valves, injection air is admitted to the top of the floating vessel, which is mounted at a certain height above the cylinder, so that the fuel flows regularly to the cylinder valves due to the head which is automatically maintained. In flowing from the floating vessel the fuel passes through an Aspinall governor valve, hand operated throttle valve, and finally through a distributing box fitted with a regulating valve for each cylinder. This arrangement has several advantages. It does away with six small fuel pumps with a large number of small valves and working parts, and substitutes a single large pump of substantial size. It is also possible on this system to provide a spare pump. A certain amount of fuel is always on hand, and even if the pump should fail, the engine will work long enough on the contents of the floating vessel to enable the engineers to start up the stand-by pump.

The other auxiliaries driven off the main engines, and which are shown on the drawing of the main engine arrangement on Plate I, are the cooling water pump, two bilge pumps, a low-pressure fuel pump for charging the filter from the settling tank, a lubricating oil pump which draws the oil from the crank pit and discharges it through a cooler to the gravity filter tanks placed high up in the engine casing, and a three-stage air compressor with intercoolers for supplying injection and manœuvring air. In order to keep down the total length of the engine these pumps and the compressor are worked by beam levers from one of the crossheads, the pumps and lever bearings being carried by one of the cast-iron columns and bedplate, as may be seen in, for instance, Fig. 9. Referring to the plan of the machinery, Fig. 13, on the port side of the vessel is fitted a three-cylinder four-stroke Werkspoor Diesel motor of 150 b.h.p., which drives an electric generator of 100 kw., and through an extension to the armature shaft, a quadruplex three-stage air compressor of Messrs. Reavell and Co.'s make. On the starboard side there is a similar Diesel motor which drives an electric generator of the same capacity as the foregoing. Arrangements are made in the wiring so that the port side generator can be used as an electric motor for driving the auxiliary compressor. These two plants are for supplying current for the electric winches, lighting, &c., when in port. For use at sea, two Kromhout semi-Diesel motors of 12 h.p. are installed, one for lighting purposes and the other for supplying current to the steering gear.

The remaining part of the engine-room equipment comprises a low-pressure fuel pump of the Roto-plunge type, electrically driven, for pumping oil from the double bottom to the settling tank; an electrically-driven ballast pump; a combined emergency set (also electrically driven), comprising a two-stage air compressor for supplying starting and injection air; a pump for supplying cooling water for main and auxiliary engines, and for bilge duties, a second pump for lubricating oil, two for Laval oil purifiers, one for lubricating oil, the other for dealing with inferior qualities of fuel oil; a lathe, drilling machine, and a large switchboard. A small oil-fired boiler is fitted for heating purposes.

An interesting fitting on the main motor is a comparative pressure-indicating device on the Hawkes-Hunter system, by which each cylinder can be tested to see if it is doing its proper share of work, without resorting to indicator diagrams, or relying on thermometers and pyrometers. The object of this indicator is to furnish some idea of what is happening in the cylinders in connection with the distribution of power, which information is intended to supplement that obtained from thermometers placed in the exhaust pipes.

It is not intended that the indicator should register

the mean effective pressure of the engine, but that it should give a comparative figure for each cylinder, so that it can be ascertained readily whether each cylinder is doing its fair share of the work. For this purpose the valve, which is operated by the cam on the indicator shaft, is opened whilst the piston of the cylinder of which the particulars are required, is passing through a definite portion of the expansion stroke. Whilst the valve is lifted, therefore, gas passes through the connecting pipe to the indicator chamber, to which a pressure gauge is connected by a short connecting pipe fitted with a hand-controlled needle valve. This reading is a measure of the mean pressure between the points on the expansion stroke corresponding with the opening and closing of the cam-operated valve of the indicator. By changing the claw of the clutch so that it corresponds successively to the various cylinders, and opening the corresponding cock, a reading may be obtained for each cylinder for comparative purposes. Should these readings agree, then it may be assumed the work done by each cylinder is approximately the same. If they differ, then by adding up the various readings a mean reading may be obtained, to which each cylinder can be set by adjusting the fuel distribution. For example, if in a six-cylinder engine the readings were, say, 140, 120, 130, 124, 136, 130, the mean would be 130. Each cylinder should, therefore, be adjusted to indicate 130.

It is assumed that the compression ratio and the maximum compression pressure are approximately the same for all cylinders, and that the fuel cams are arranged to give the same maximum gas pressure in each. To check the indicator, indicator cards are taken from each cylinder and the mean pressure worked out. Any differences between the mean pressures as determined from the indicator cards of the several cylinders should correspond, but to a slightly smaller extent, to the differences as shown by the mean pressure indicator.

In connection with the machinery of this vessel, it may be mentioned that this was the first single-screw Diesel-engined ocean-going vessel built in this country in which the motors were installed without previous shop or land trials, and that the vessel was handed over to the owners in less than two weeks from the time that the engines were first run on oil fuel by the makers, who, as already stated, were the North-Eastern Marine Engineering Company, Limited.

## NEW YEAR HONOURS.

THIS year's New Year Honour List is consistent with its predecessors in regard to the rather small number of members of the engineering and related professions included. We notice among the list of new baronets the name of Lieutenant-Colonel Sir Henry Mulleneux-Grayson, K.B.E., M.P. for Birkenhead, the Liverpool shipbuilder. He acted as High Sheriff of Anglesey during the years 1917–18, and during the war was also Director of Ship Repairs (Admiralty). A baronetcy has also been conferred upon Mr. David Richard Llewellyn, J.P., chairman of the Llewellyn Shipping Company, and chief partner of Llewellyn, Merrett and Price, Limited; also chairman of many colliery companies. Mr. James Readhead, J.P., and Mr. Hugh Reid, C.B.E., LL.D., D.L., J.P., are, among others, also to receive baronetcies. Mr. Readhead is chairman and managing director of the well-known firm of John Readhead and Sons, Limited, shipbuilders, while Mr. Hugh Reid is the chief managing director and deputy-chairman of the North British Locomotive Company, Limited, Glasgow.

Among the knights we notice the name of Mr. C. R. S. Kirkpatrick, the chief engineer of the Port of London Authority, and that of Mr. William Graham, J.P., chairman and managing director of the Cardiff Dry Dock and Engineering Company, and other important concerns. Mr. Harry Greer, Member of Parliament for the Wells Division of Somerset, chairman of the Board of Trade Committee, Merchandise Marks Act, and of the late Lord Roberts' Memorial Workshops; and Mr. A. J. Hobson, president of the Association of Chambers of Commerce of the United Kingdom, 1920–21, are also to be knighted by His Majesty.

Among the recipients of Orders of the Indian Empire is the name of Sir John Harvard Biles, consulting naval architect to the India Office, who becomes a K.C.I.E. Sir John was created a knight in 1913, in recognition of his services on Government Committees during the preceding ten years. He has been consulting naval architect and engineer to His Majesty's India Office since 1907, and is responsible for the designs and construction of vessels built for the Government of India. During the war he was largely engaged in the superintendence of design and construction of about 274 vessels for Mesopotamia. His firm is responsible for the superintendence of design and construction amongst others of the four vessels which have been built, or are building, for the Canadian Pacific Railway Company, two by Clydebank and two by Fairfield. These vessels were planned under the direction of H. Maitland Kersey, D.S.O., and when the order for the building was given the designs were prepared by the builders, and these and the construction were carried out under the superintendence of Sir J. H. Biles and Co., acting on behalf of the Canadian Pacific Railway Company. Mr. A. J. R. Hope, late superintending engineer, Simla Imperial Circle, and Mr. J. W. Meares, electrical adviser to the Government of India, will receive the distinction of C.I.E.

## "HYGROMETRY."

TO THE EDITOR OF ENGINEERING.

SIR,—In your issue of December 30, on page 891, in an article entitled "Hygrometry," and referring to a recent discussion on this subject by the Physical Society, there appears a statement in the last paragraph that "Dr. W. O. Normand, of Simla, was now approaching the problems from the thermodynamic standpoint, by considering the changes as adiabatic and those considerations seem to put the theory on a sound basis."

The problems referred to were the inter-relationship of the wet and dry bulb readings, and I should like to point out that Mr. W. H. Carrier, in a paper read before the American Society of Mechanical Engineers in December, 1911, entitled "Rational Psychrometric Formulæ," deduced from thermodynamic principles and proved experimentally the inter-relationship between the wet and dry bulb thermometers, and Mr. Carrier was, I believe, the first physicist to consider the changes as being adiabatic.

The paper referred to above is undoubtedly the most valuable contribution to the science of hygrometry which has been put forward within recent years, and I am astonished that the Physical Society are apparently unaware of Mr. Carrier's researches in this field.

Yours faithfully,

CARRIER ENGINEERING COMPANY, LIMITED,
C. T. G. HOOPER, A.M.I.Mech.E., Chief Engineer.
24, Buckingham Gate, London, January 2, 1922.

## "ENGINEERING AS A PROFESSION."

TO THE EDITOR OF ENGINEERING.

SIR,—As an engineer of some twenty-five years standing, my advice is, "shun it like the plague." At 40 years of age it may be too late to change, but I can see to it that my son is not victimised as I have been, in the civil engineering profession.

One could give illustrations innumerable in support of this advice, which is based on long experience and on fact. Conditions might be much improved if the parent body were more alive to the interests of its members, and in a position to protect them from exploitation, but unhappily, it is not. I enclose my card.

Yours faithfully,
"CORPORATE MEMBER INST.C.E."

January 3, 1922.

## "THE DISPOSAL OF LONDON REFUSE."

TO THE EDITOR OF ENGINEERING.

SIR,—We have read with interest your leading article on the disposal of London refuse, and in view of its bearing on public health, the report of the committee may quite fairly be said to be of national importance. Amongst the many lessons taught by the war was the necessity for economy and the value of waste products, and it is interesting to note that the report lays great stress on the advantages of salvaging. Our firm was one of the first to realise that there was commercial value in the old tins and scrap metal found in such large quantities in the refuse of every large town, and we were pioneers in introducing a cheap and efficient type of machine for dealing with this. The destructor plant at Hornsey and also at Marylebone, to which you refer in your article, are both equipped with our presses, and during the last few years upwards of 400 of these machines have been supplied, and they have proved a paying proposition. The great point is that these old tins have to be dealt with in some way or other—they cannot be burnt or buried; in the loose state no one wants them, but on the contrary they cost money to cart away and dump. If they are baled into compact bundles, they become a marketable commodity, and even though the price they command is not high, they at least constitute an asset and not a liability—a most important point in these days of municipal economy. The process of baling reduces the volume to about one-eighth and makes a tight and self-contained bundle. A huge stack of unsightly and useless old tins is soon reduced to a neat pile of compact bales, taking little space, readily saleable and costing little for transport, giving ample confirmation of the conclusion you draw from a study of this report that salvaging is the most economical and practical way of dealing with town's refuse generally.

Yours faithfully,
G. N. GUEST,
For and on behalf of HOLLINGS AND GUEST, LIMITED, BIRMINGHAM.

January 3, 1922.

PROSPECTING FOR OIL IN AUSTRALIA.—Numerous applications have been received in Darwin, Northern Territory, and Melbourne, for licences to prospect for oil. The blocks cover an area of 1,000 sq. miles. They extend from Taninui goldfield to the Gulf of Carpentaria, and include some coastal islands, as well as inland territory.

## NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

*Iron and Steel.*—There are very few indications of improvement in the Sheffield industries. During the Christmas stoppage a few inquiries and one or two orders have been received, but these do not seem to point to a general improvement. A quiet time is anticipated for most of the works in this district, and buyers who were considering the advisability of placing orders are now awaiting further developments with regard to railway freights. There is practically nothing doing in the ferro-alloy section. Bookings in the crucible steel trade are at low ebb. The market for high-speed steel remains as stagnant as ever, and the sale of tungsten is about nil. Carbon-free ferro-chrome is in demand by manufacturers making rustless iron, and substantial quantities of this are now being sold. The price of nickel is officially reduced to 180*l.* per ton, both for home and export. The slump in the cutlery and plate trade continues. The razor section has been the hardest hit, and some makers declare that they have only sold odd lots now for months, most of the trade going over to Germany. Business in cutlery and plate factories is suspended for a fortnight, and the opportunity is being taken to overhaul plant and machinery. The demand for farm and garden tools is restricted, buyers are apparently waiting for a further decline. There has been no trade with Irish customers, who are holding off for the same reason.

*South Yorkshire Coal Trade.*—Holiday influences still prevail in the South Yorkshire coal market, the demand for industrial fuel being very limited. Many of the big concerns have not yet started work and business at the steam coal pits is very slack. The export trade is also quiet, though numerous inquiries on the market indicate an early and substantial improvement. A steadier tone is noticeable in small fuel, due to the heavy consumption at collieries and coke ovens during the holiday period. The putting into blast of any substantial number of furnaces would have a marked effect on this class of fuel. Coke is moving freely with prices well maintained. A capital start has been made at most of the house-coal pits. The demand from all quarters is brisk, and from the London area particularly heavy. The reduction in railway rates has only affected local depots a few pence per ton, and is not sufficient to cause any marked alteration in values. Quotations:—Best branch handpicked, 39*s.* to 40*s.*; Barnsley best Silkstone, 38*s.* to 40*s.*; Derbyshire best brights, 35*s.* to 36*s.*; Derbyshire best house, 34*s.* 6*d.* to 35*s.*; Derbyshire best large nuts, 30*s.* to 32*s.*; Derbyshire small nuts, 27*s.* to 29*s.*; Yorkshire hards, 29*s.* to 30*s.*; Derbyshire hards, 28*s.* 6*d.* to 29*s.* 6*d.*; rough slacks, 17*s.* to 18*s.*; nutty slacks, 15*s.* to 16*s.*; smalls, 5*s.* to 10*s.*

## NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

*The Cleveland Iron Trade.*—Holidays are still interfering with business, but there is a better feeling in Cleveland pig-iron, and expansion of trade in the near future is looked for. Quotations are expected to fall, but as yet the following rates rule: No. 1 Cleveland pig-iron, 105*s.*; No. 3 G.M.B., 100*s.*; No. 4 foundry, 95*s.*; No. 4 forge, 90*s.*; mottled, 85*s.*; and white iron, 85*s.*

*Hematite.*—East Coast hematite is now well taken up, substantial home and export sales having been made. The re-starting of more furnaces before long is not improbable. No. 1 is firm at 102*s.* 6*d.*, and Nos. 1, 2 and 3 are 100*s.*

*Foreign Ore.*—Whilst foreign ore is still stagnant, sellers take a more hopeful view of the future. Though most consumers continue to carry considerable stocks, and have rather large arrears of delivery to take up against old contracts, some firms, whose plant has been in operation are not now so favourably placed, and may be in the market to buy shortly. The c.i.f. price of best rubio is round about 26*s.* 6*d.*

*Manufactured Iron and Steel.*—Works are closed for the holidays. Orders are difficult to secure, and quotations weak. Export business can be put through at below the following figures, which are among the principal quotations to home customers. Common iron bars, 12*l.* 10*s.*; iron rivets, 14*l.* 10*s.*; soft steel billets, 7*l.* 10*s.*; medium steel billets, 9*l.*; hard steel billets, 9*l.* 10*s.*; steel ship, bridge and tank plates, 10*l.* 10*s.*; steel angles, 10*l.*; steel joists, 10*l.* 10*s.*; heavy steel rails, 9*l.* 10*s.*; fishplates, 14*l.* 10*s.*; and corrugated galvanised sheets, 17*l.*

*Shipments of Iron and Steel.*—Shipments of iron and steel from the port of Middlesbrough last year totalled 449,362 tons, against 750,570 tons in 1920. The 1921 December clearances reached 66,612 tons, 14,288 tons of which went coastwise, and 52,324 tons to foreign destinations. Of 18,931 tons of pig-iron despatched last month 9,500 tons went coastwise and 9,431 tons went abroad; of 5,465 tons of manufactured iron cleared 426 tons went coastwise and 5,039 tons went abroad; and of 42,216 tons of steel loaded, 4,362 tons went coastwise and 37,854 tons went abroad. Among the largest customers for pig-iron were: Wales, 7,520 tons; Switzerland, 2,400 tons; Belgium, 2,166 tons; Italy, 1,915 tons; Norway, 1,250 tons; and Scotland, 900 tons; India was again the largest importer of both manufactured iron and steel, receiving 4,340 tons of the former, and 10,623 tons of the latter. Other large buyers of steel were: Argentine, 6,292 tons; New Zealand, 5,773 tons; Nigeria, 3,934 tons; Japan, 2,132 tons; British South Africa, 1,631 tons; Natal, 1,118 tons; and New South Wales, 1,043 tons.

## NOTES FROM THE NORTH.

GLASGOW, Wednesday.

*Scotch Steel Trade.*—There is nothing doing in the Scottish Steel trade at the present time as all the works are off for the holidays and buyers are not yet convinced that prices have reached rock bottom. Reports to hand do not indicate anything in the way of an early opening-out of business, and a "wait and see" policy is being followed all round. The results of the past year have been far from satisfactory, and as the different phases through which the trade has passed have been followed very closely little purpose will be served by more than mention of the chief points. A year ago the bulk of the old bookings had been cleared off and the outlook was somewhat uncertain, and producers resolved to make reductions in their prices. These commenced very guardedly and a similar policy has been followed all the year with the result that buyers would not be induced to give out orders. While producers knew their own business best and made only small reductions periodically, many held the view that one or two good reductions would have helped to stimulate trade. On-cost charges in this country have remained very high and this acted in favour of the foreigner who, aided also by the rates of exchange, was able to deliver steel material here at prices considerably less than those asked for by the local makers. The result of this was that many orders were booked for the Continental works, which have been kept going steadily all the year. One thing which greatly benefited the latter was the disastrous strike of three months of the British miners. Since that time trade in this country has never shown signs of looking up until now, when there are visible signs of improvement, and by the spring it is generally anticipated the large number of unemployed will be considerably reduced. The months of October and November were very important ones in the steel trade on account of the dissolving of the selling agreements between the English and Scottish makers. Firstly it was decided that each association should fix its own prices, but that territorial arrangements should remain in force, but this was later followed by the scrapping of the agreement, and with the exception of boiler plates it was decided to free prices. Since that time some very severe competition has taken place for any orders on offer, and this state of affairs will likely continue until trade revives and it is agreed to end that cut-throat policy, in a modified kind of way, at any rate. The de-control of prices has been in favour of the buyers, but few of them have given out more than actual requirements yet, although it is fairly well known that quite a lot of business could be and probably will be placed in the near future. As already stated, prices have shown a steady decline as the following indicates :—

| | Jan. 1, 1921. Per Ton. £ s. d. | Jan. 1, 1922. Per Ton. £ s. d. |
|---|---|---|
| Boiler plates ... | 31 10 0 | 14 0 0 |
| Ship plates ... ... | 25 15 0 | 10 10 0 |
| Angles ... ... | 24 10 0 | 10 0 0 |
| Steel sheets, ¼-in. ... | 29 0 0 | 12 5 0 |

The quotations given as ruling to-day for ship plates and angles are really only nominal because favourable specifications are quoted for at lower rates in the hope of securing business to keep plant running. An export order for ship plates was reported the other day as having been taken about 8*l.* 15*s.* per ton f.o.b.

*Malleable Iron Trade.*—The West of Scotland malleable iron trade has passed through rather a thin time during the past year, and it cannot be said that the outlook for the year 1922 is at all reassuring. Inquiries at present in the market do not amount to a heavy tonnage, but there are high hopes that an improvement will take place before long. Prices have fallen by more than a half since a year ago when the basis price for "crown" bars was 27*l.* 10*s.* per ton, whereas to-day makers are quoting 12*l.* 10*s.* per ton. Complaint has been made that prices were not reduced quickly enough, but against that can be put the high on-cost charges which have prevailed. The home trade has been very quiet, while the export trade has only been like a shadow of its former self. This latter state has been largely due to the favourable position of Belgium and Germany, as much lower prices have prevailed in these countries. Financial conditions abroad have also been against business.

*Scottish Pig-Iron Trade.*—Since the closing down of the various works for the holidays there has been practically nothing doing, and inquiries are not very encouraging. With so few orders on hand the Scottish pig-iron makers are not over anxious to light up their furnaces, and few of these will be re-kindled for some time. The state of trade during the past year is easily followed by references to the number of furnaces which were in operation. The total available for production of pig-iron is over 100, but a year ago those in blast numbered 63, while by the end of the first quarter the total had been reduced to about 40. Then came the miners' strike, with the result that all but six furnaces were put out of blast, and none of these continued working longer than four or five weeks. When the strike was over a limited number were relighted, but owing to the poor demand a reduction gradually took place, and by the close of the year there were no more than nine in blast. The prices which the Scottish ironmasters found it necessary to ask for pig-iron were a good way more than the Continental iron could be delivered at, with the result that there was a very free importation, and by judicious mixing with some of the home makes quite a satisfactory product was obtained by consumers. There is less inducement now to dabble in the foreign makes as local prices have fallen considerably over the year, and whereas No. 3 foundry iron was round 13*l.* per ton last January it is quoted to-day at 5*l.* 15*s.* per ton, and No. 1 at 6*l.* per ton. The export trade has been very much "off" all year, and the high railway rates have considerably reduced our trade with England. Hematite iron has been in very poor demand for the past twelve months, chiefly through the depressed condition of the steel trade. The number of furnaces turning out hematite iron had been reduced, and the three which were lighted up after the miners' strike was settled were more than equal to all the demands, and before the end of the year even that small number were blown out. The price has not been remunerative, and from 13*l.* per ton a year ago the quotation has fallen to-day to round 6*l.* per ton delivered at the steel works.

## NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

*The Coal Trade.*—Another strike is threatened in South Wales. At a special meeting of the Conciliation Board for the coal trade held yesterday allegations were made by the miners' leaders that the men were being kept on the minimum wage, which is insufficient to meet the cost of living, being 20 per cent. above 1914 average earnings, by the needless cutting of prices on the part of the owners. It was contended that the immediate cause of the low prices and reduced revenue was needless competition in the sale of coal, and that this price-cutting could be avoided by proper organisation and a more co-ordinated policy in connection with sales. The men threatened that unless steps were taken by the owners to remedy the existing evils and bring about an increase in wages the men would take the matter in their own hands, and this would result in a stoppage of work. The owners pointed out that the miners themselves were responsible partly for the present position, and that it was only by successful competition that South Wales could recover its trade and provide regular employment at increasing wages. Mr. Evan Williams, chairman of the owners' side of the Board promised to report the miners' case to the Coalowners' Association. The sale of the coal produced from the pits of the Blaenavon Company has been transferred to the Maris Export and Trading Company, Limited, Cardiff. This company has a capital of 250,000*l.*, which is held by the Powell Duffryn Coal Company, the Normandy Shipping Company and Messrs. Stephenson, Clarke and Co. The Blaenavon Company owns four collieries with an output of about 800,000 tons of Monmouthshire coal per annum. The market has not yet settled down from the effects of the holiday stoppages. The recent gales has also upset arrangements, for shipping has been thrown out of position with the result that prices are irregular and dependent on individual circumstances. Generally, best Admiralty large is quoted at 25*s.*, and best steam smalls at 17*s.*, but for spot delivery small discounts could be secured. Exports of coal as cargo to foreign destinations in the past year totalled nearly 12,000,000 tons compared with 15,500,000 tons in 1920 and nearly 30,000,000 tons in 1913.

*Iron and Steel.*—The demand for Welsh tin plates is inactive and prices show a weaker tone. The outlook is none too bright, for at current values makers cannot show a profit, and it is feared that some of the mills will have to close down again. For this month's delivery 19*s.* 9*d.* f.o.b. has been accepted, and for February-March buyers offer 19*s.* 3*d.* Galvanised sheet prices are lower, and 16*l.* 10*s.* per ton f.o.b. is offered for corrugated in bundles. Supplies of scrap are in excess of the demand. Heavy steel scrap is from 65*s.* to 70*s.*, bundled steel scrap and shearings 50*s.* to 65*s.*, and good machinery scrap from 4*l.* 5*s.* to 4*l.* 15*s.*

INTERNATIONAL FOUNDRY TRADES EXHIBITION.—An international foundry trades exhibition is to be held in Bingley Hall, Birmingham, from June 15 to 24 next. It has been organised by the Birmingham Chamber of Commerce (Inc.) in conjunction with the Institution of British Foundrymen and the British Cast-Iron Research Association. The president is the Right Hon. Lord Weir of Eastwood. All communications should be made to the General Manager of the Exhibition, Chamber of Commerce, 95, New-street, Birmingham.

ELECTRIC MACHINERY FOR SYDNEY.—The Municipal Council of Sydney (Electricity Department) invite tenders for the supply, delivery and erection of : (*a*) Two 2,000-kw. rotary converters, (*b*) One 10,000-kw. to 12,000-kw. turbo-alternator. Sealed tenders on proper forms will be received by the Town Clerk, Town Hall, Sydney, up to 3 p.m. on April 24. A preliminary deposit of 100*l.* must be lodged with the City Treasurer at Sydney before the time specified for the closing of tenders. Specifications, conditions and blue prints relating to these contracts may be consulted by United Kingdom firms interested, on application to the Department of Overseas Trade (Room 49), 35, Old Queen-street, London, S.W. 1.

FIFTY-THREE-INCH TYRE MOULD AND CORE BORING AND TURNING MILL.—ERRATUM.—We very much regret that owing to an oversight the 53-in. tyre mould and core boring and turning machine illustrated in our last issue (page 888, vol. cxii) was described as intended for railway wheels. The machine has been, as a matter of fact, designed specially by the makers, the Niles-Bement-Pond Company, of New York, U.S.A., to stand up to the heavy work required in turning out moulds for rubber tyres. The finishing of these moulds of cast-iron, involves very wide finishing cuts being taken, and the surface must be smooth and absolutely free from shatter. The machine in question has been evolved primarily for this duty, and the feeds and speeds arranged are specially adapted to this class of work.

## NOTICES OF MEETINGS.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, January 6, at 6 p.m., Joint Meeting with the Society of Chemical Industry. "The Co-operation of the Engineer and Chemist in the Control of Plants and Processes," by Mr. G. M. Gill, Member.

THE BRADFORD ENGINEERING SOCIETY.—Monday, January 9, at 7.30 p.m., Joint Meeting with the Yorkshire Association of the Institution of Civil Engineers. Lecture in the Hall of the Bradford Technical College by Mr. Lewis Mitchell, M.Inst.C.E., waterworks engineer, Bradford, on "The Bradford Water Supply," illustrated by lantern slides.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Monday, January 9, Discussion on "Co-operative Advertising in Relation to the Electrical Industry." To be opened by Mr. J. W. Beauchamp. Mr. A. B. Eason in the chair.

THE INSTITUTE OF TRANSPORT.—Monday, January 9, at 5.30 p.m., at the Institution of Civil Engineers, Great George-street, Westminster, S.W. 1, "Transport Law," by Sir R. Francis Dunnell, Bart., K.C.B., Member.

THE SURVEYORS' INSTITUTION.—Monday, January 9, when a paper will be read by Mr. W. R. Davidge (Fellow) on "Problems of Greater London." The chair will be taken at 8 p.m.

THE INSTITUTION OF ELECTRICAL ENGINEERS : SCOTTISH CENTRE.—Tuesday, January 10, at 7 p.m., at the North British Station Hotel, Edinburgh. Paper : "Induction Type Synchronous Motors," by Mr. L. H. A. Carr.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.—Tuesday, January 10, at the Royal Society of Arts, John-street, Adelphi, W.C. 2, the following paper will be read by Mr. W. R. Ormandy, D.Sc., F.I.C., F.C.S., M.I.A.E., and E. C. Craven. "An Investigation into the Physico-Chemical Significance of Flash Point Temperatures." The chair will be taken at 5.30 p.m. by the president, Professor J. S. S. Brame, F.I.C., F.C.S.

INSTITUTE OF METALS : SCOTTISH LOCAL SECTION.—Tuesday, January 10, at 7.30 p.m., at the Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank-crescent, Glasgow. "Internal Stress in Metals," by Mr. A. Melanoc, D.Sc., A.R.S.M.

THE JUNIOR INSTITUTION OF ENGINEERS.—Tuesday, January 10, at 2.30 p.m., visit to the Charlton Works of the United Glass Bottle Manufacturers, Limited. Thursday, January 12, at 6 p.m., official visit to the Model Engineer Exhibition at Royal Horticultural Hall, Vincent-square, Westminster. Friday, January 13, at 7.30 p.m., at Caxton Hall, Extraordinary General Meeting. At 8 p.m., Ordinary Meeting, paper "Artificial Ice," by Mr. E. C. West (Chairman).

THE INSTITUTION OF CIVIL ENGINEERS.—Tuesday, January 10, at 6 p.m. Papers to be read : "Control of Trains in Relation to Increased Weight and Speed Combined with Reduced Headway," by Mr. Alan Wood Rendell, M.Inst.C.E. ; and "Trials in Connection with the Application of the Vacuum-Brake for Long Freight Trains," by Sir Henry Fowler, K.B.E., and Mr. Herbert Nigel Gresley, C.B.E., M.Inst.C.E. STUDENT'S MEETING, Wednesday, January 11, at 6 p.m. The first of two Lectures on "The Economic Aspects of Various Methods of Power-Transmission," by Mr. E. W. Monkhouse, M.A., M.Inst.C.E. The president will occupy the chair. Members of all classes are invited to attend these lectures.

THE ASSOCIATION OF ENGINEERS-IN-CHARGE.—Wednesday, January 11, at 7.30 p.m., at St. Bride's Institute, Bride-lane, Fleet-street, E.C. 4, a paper will be read by Mr. B. P. Flockton, M.I.Mech.E., on "Machinery for the Production and Refining of Edible Oils for Margarine, &c." (Illustrated by lantern slides.) Professor J. W. Hinchley, A.R.S.M., Whit. Sc., F.I.C., in the chair.

THE INSTITUTE OF METALS : LONDON LOCAL SECTION.—Thursday, January 12, at 8 p.m., at the Sir John Cass Technical Institute, Jewry-street, Aldgate, E.C. 3. "Inner Structure of the Crystalline Grain," by Colonel N. Belaiew, C.B.

THE OPTICAL SOCIETY.—Thursday, January 12, at 7.30 p.m., at the Imperial College of Science and Technology, South Kensington, S.W. 7. The following papers will be presented : "The Manufacture of Optical Glass," by Dr. C. J. Peddle, M.B.E., F.I.C., F.Inst.P. ; "The Barr and Stroud 100-ft. Self-contained Base Range-finder," by Dr. James W. French, F.Inst.P. ; "The Optical Three Apertures Problem," by Mr. T. Smith, M.A., F.Inst.P.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, January 12, at 6 p.m., Exhibition of Cinematograph Films. The following cinematograph films will be exhibited : (*a*) "Investigations and Tests on High-Tension Switch Gear," by Mr. P. Torchio, with explanatory notes by Dr. C. C. Garrard ; (*b*) "Telephone Inventors of To-day," exhibited by Mr. F. Gill ; (*c*) "The Audion," exhibited by Mr. F. Gill ; and, if time permits, (*d*) "Electricity in the Home," exhibited by Mr. F. Gill.

THE INSTITUTION OF BRITISH FOUNDRYMEN : LANCASHIRE BRANCH.—Saturday, January 14, at 4 p.m., in the College of Technology, Manchester, when Dr. P. J. Brisley, of Roby, Lancashire, will give a paper on "The Solution Theory of Alloys, with Special Reference to Cast Iron."

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(*For Description, see Page* 12.)

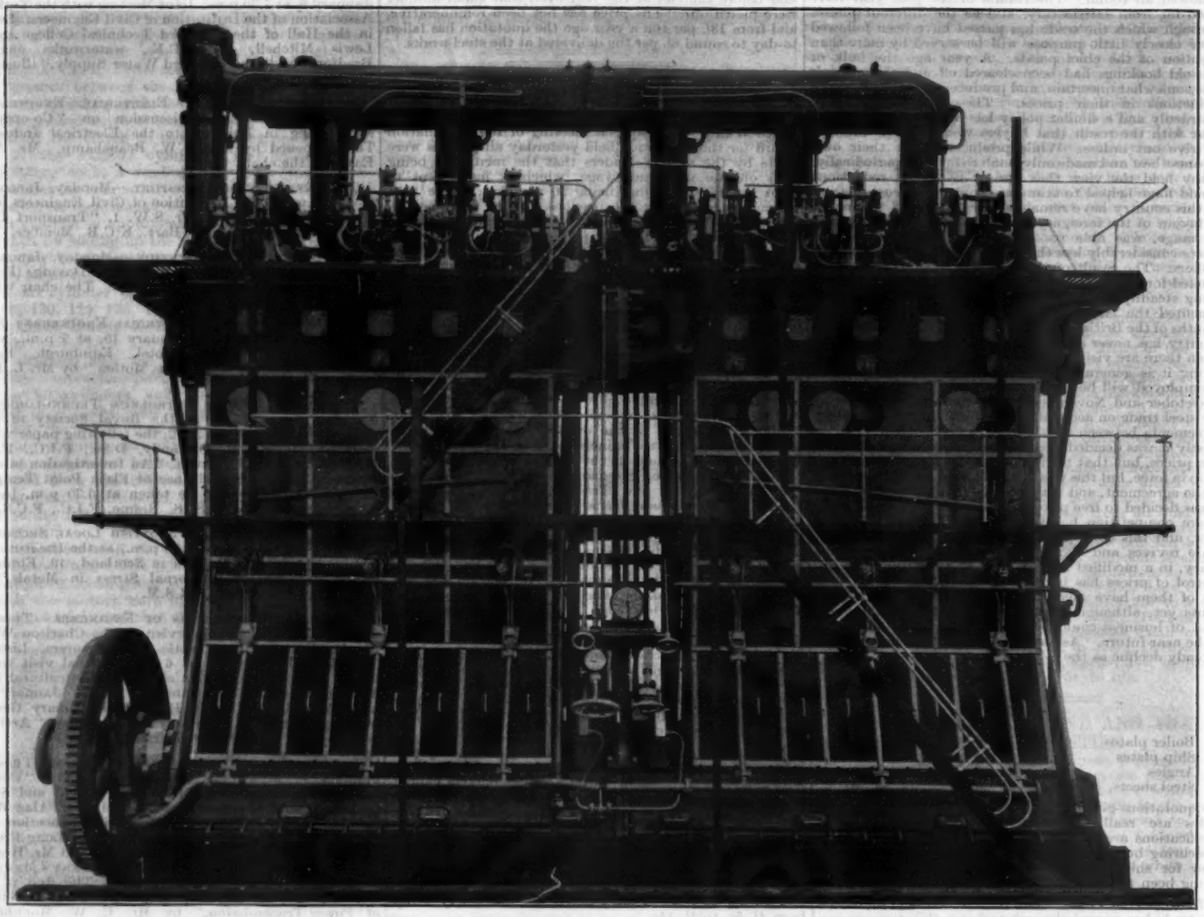

FIG. 21. THE MAIN ENGINES.

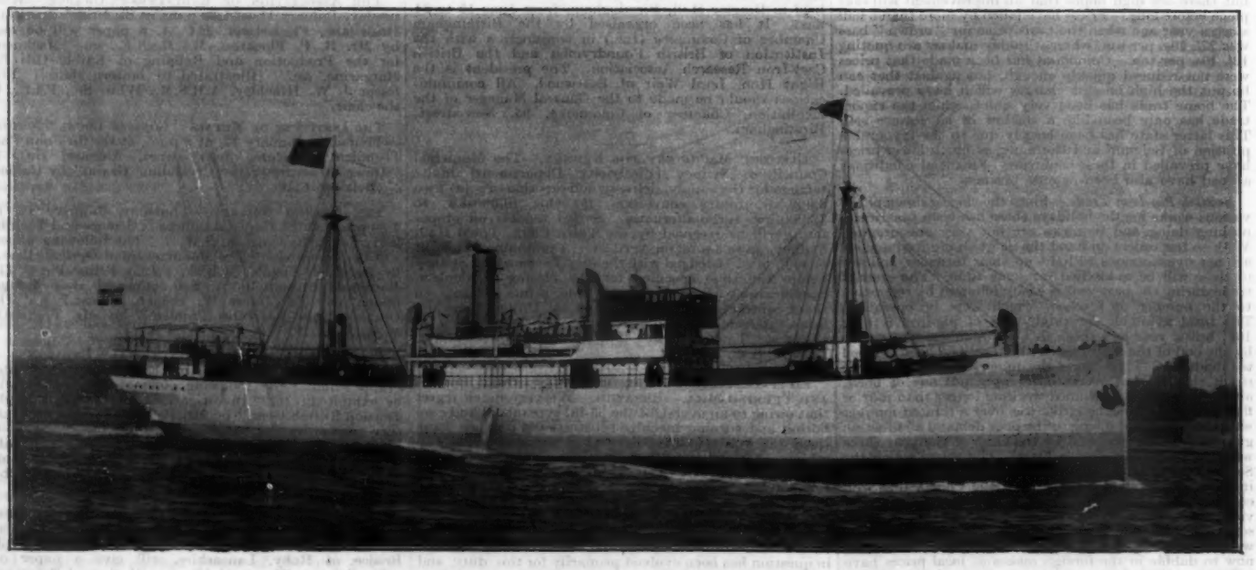

FIG. 22. THE SHIP ON TRIAL.

# ENGINEERING.

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*Two-Page Plate:*—1,400-I.H.P. *WERKSPOOR DIESEL ENGINE FOR THE MOTOR SHIP "SEVILLA."*


# ENGINEERING.

*FRIDAY, JANUARY* 6, 1922.


## THE RESEARCH WORKERS' TRADE UNION.

THE copybook headings of the past were perhaps not wholly prudent in impressing upon the rising generation the somewhat unattractive adage that virtue constituted its own reward. The pursuit of science has commonly suffered under a similar disability. Even at our schools and colleges the specialist in classical studies has received far more generous treatment than the student of nature and nature's laws, and this example has been largely followed by our Government Departments where scientific or technical acquirements often appear to be regarded almost as a disqualification for one of the higher administrative posts. Fortunately, however, each generation comprises some individuals who, like the men of ancient Athens, are continually hankering after some new thing, and such men have ever found, in the joy of adding something fresh to the sum total of human thought, their main recompense for sleepless nights and laborious days devoted to original research.

This temperament has undoubtedly been somewhat shamelessly exploited in the past, and though matters improved somewhat during the war many scientific workers have been driven to the conclusion that only in the adoption of trade union methods can a panacea be found for this condition of affairs. The result was the formation of a National Union of Scientific Workers. There is much to regret in this decision, which at the best is merely, as Bacon said of usury, a concession to man's hardness of heart, and it is exceedingly difficult to see how success will be possible along the ordinary lines of trade union activity. It is true, of course, that something like a strike was needed to secure fair treatment for Army doctors, but the medical man stands in a very different position to a research worker. Not merely has Parliament given the medical profession far-reaching powers of self-government, but the medical man is an immediate necessity, whilst society at large, a public department in particular, or an individual firm, would not be seriously inconvenienced by a temporary withdrawal of labour from research work. An investment in the latter is essentially a bill drawn on the future, and a speculative venture at the best. A discovery made in the laboratory is rarely immediately profitable. Fairy stories have no doubt been told by a well-known worker on radio-activity to the effect that a chemist "might be able to put on half a sheet of notepaper that which would keep a whole class in the community in prosperity for a generation." Such assertions, however, receive no support from the history of applied science, as the practicalising of laboratory processes has ever involved the assumption by some one of heavy financial risks in addition to a great expenditure of thought and industry. Several fortunes were lost by enterprising undertakers before the ammonia soda process was made a success, and methods of catalysis quite successful in the laboratory proved for long merely costly failures in works practice.

Whilst, therefore, research is all important for the future progress of an industry, its present value, in the actuary's sense of the word, is generally small, and the punishment for neglect, inevitable though it may be, is often postponed for years. The prospect of a research trade union being able to enforce its views by a withdrawal of labour is accordingly small, and the most powerful weapon of the industrial trade union is thus lacking.

It is not, however, surprising that the union has already many adherents, since whilst the best class of research worker will always find his main reward in the consciousness of good work done, there has been gradually growing up a large body of scientific auxiliary men who carry out a vast quantity of research of the made-to-order type, and which though essential to progress, does not require in those who pursue it striking originality or even keen enthusiasm, but merely a certain degree of ingenuity, honesty and industry.

Research workers of this class are largely interchangeable *inter se* and accordingly have in many cases been far from liberally treated in the past, Government Departments being amongst the worst sinners. Such men, no doubt, will supply the majority of the members of the union which, however, is bound to suffer from the circumstance that it can be of little or no advantage to the first-class man. In this respect conditions in research work are not dissimilar to those characteristic of the drawing office. In both cases the exceptional man, who outweighs in his importance to the community a hundred of the average, is more likely to be hampered than helped by belonging to a union. First class work, either in the laboratory or in engineering design, is essentially individualist in character. Indeed, Sir George Beilby has stated that when he commenced some of his most successful investigations he would have had difficulty not merely in justifying his undertaking to a committee but even in clearly specifying his aims. In fact, it is often the initial stage of formulating an issue that makes the heaviest draught on the insight of an investigator, and once this is accomplished, the actual work of verification might in many cases be confided to men themselves quite incapable of the preliminary feat. It may, moreover, be observed that first-class men cannot be successfully exploited. No pressure of authority could have compelled James Watt to invent the separate condenser, or Faraday to discover magneto-electric induction, or Carnegie to develop the American steel industry. It is only in work of the hodman type that either an individual firm or a community can exact a daily tale of bricks. The really great discoverers and organisers, in short, do not work at set tasks. It is their function to find out on what tasks the average clever man can be best employed.

The Union of Scientific Workers appears to be exercised at the differing rewards received by inventors. Indeed, Professor Bairstow observes that the patenting of a simple idea may yield an inventor a reward quite disproportionate "to his work of invention." Apparently, therefore, he would graduate the award in proportion to the labour

expended rather than to the result achieved. Hence a discovery made by a stupid worker expensively and laboriously, would be paid for more highly than if by insight and intuition a really able investigator had arrived quickly and cheaply at the same result. Such a principle would prove most pernicious in practice, and moreover, if admitted, could hardly be confined to scientific workers alone. The compilation of an important philosophical or scientific treatise, for instance, involves far more strenuous labour than the production of a popular novel or play, but without such a social upheaval as would put an end to the production of both types of literature, the Wells's and the Shaw's will always profit more in their generation than those who make really valuable contributions to human thought.

The Union of Scientific Workers hold that the value of any invention made by a scientific worker should be covered by his salary, and we have heard the same contention urged by an important employer who maintained the thesis that any invention made by a manager, draughtsman, workman, or foreman should belong of right to his employer. We think this view is not merely bad ethics but bad policy, and it is somewhat surprising to find it pressed on the Departments of State by the union.

Unfortunately, however, there is abundant evidence that many scientific workers cease to think scientifically once they get outside of their laboratories. The same man, who if confronted with a proposed new experiment in, say, the phenomena of radio-activity, would show becoming diffidence in predicting the result, will if he turns to the discussion of the much more complicated problems presented by experiments in economics or sociology express himself most positively as to what will be the outcome.

The report of the union upon this matter of the reward for invention discloses no trace of any study of past experience, but the conclusions are apparently based purely on deduction from hypothetical premises. In view of the great success achieved by the research departments of the German chemical factories, it would certainly have been well to have studied and stated the methods of reward followed there, before formulating the policy of the union.

In yet another matter the union appears to have been guided by the light of nature rather than by the dictates of experience. They criticise the department of Scientific and Industrial Research for establishing research associations which hand over "to profit-seeking monopolies valuable knowledge obtained at the expense of the whole community."

This protest seems more sonorous than sound. Indeed it is not quite clear what the committee have in view. In most cases the research associations are only partially financed by the department, and the term monopoly also requires definition. Nowadays it is too frequently used merely as a term of abuse. Even were the situation adequately defined in the words quoted, it by no means necessarily follows that the policy condemned is against the public interest. The famous glass works at Jena have acknowledged in their own publications the liberal assistance received from the Prussian Government. As one result of this the firm acquired at the cost of the community knowledge which secured to them a world monopoly in many kinds of optical glass. It can hardly be contended that this result was other than advantageous to the German nation at large. In short, the wisdom or otherwise of the policy adopted by the Advisory Council for Research certainly cannot be settled offhand by specious generalisations.

For the reasons advanced in the earlier part of this article, it would seem that the union has little to hope for by the adoption of ordinary trade union methods. It may, however, do good by bringing moral pressure both on government departments and on private firms, and thereby induce them to treat more wisely and more generously the rank and file of their technical and scientific staffs, but success in this direction will hardly be achieved without a very distinct change in the tone and character of the union's present proceedings.

## CHROMIUM STEELS.

THE constitution of chromium steels forms the subject of a Carnegie scholarship memoir by Mr. Thomas F. Russell (Sheffield), presented to the Iron and Steel Institute in March of last year. These alloys, as is well known, require particular care in their preparation and heat treatment; they have found comparatively lately numerous applications in fields which are very far apart, such, for example, as the manufacture of armour-piercing shell—the armour itself being of nickel-chromium steel—the manufacture of plates for safes, of certain parts of stone-breaking machinery, whilst a later application is the manufacture of "stainless" articles and machinery parts, one which promises for them an extensive range of usefulness. The subject of the memoir is therefore a present-day one.

The author dealt in his experiments with 19 chromium steels made by Messrs. Peter Stubs, Limited, Rotherham, manufactured from best Swedish iron, ferro-chrome, and either metallic chromium or charcoal, by the usual Sheffield "white clay" crucible process. These were a very pure series of iron-chromium alloys, but the variation in carbon and chromium, which was intended to be from 0·25 per cent. to 1 per cent., and from 1·50 per cent. to 12 per cent., was not as good as he would have desired. Five more steels were therefore made at Sheffield University; these contained from 0·44 of carbon and 5·46 of chromium, to 0·65 of carbon and 13·34 of chromium. In the two instances here cited, the chromium added was respectively 6·06 per cent. (from ferro 2·64 and from chromium metal 3·42) and 14·05 per cent. (4·66 and 9·39); whilst in the case of the first alloy, showing 0·44 per cent. of carbon, the carbon added was 0·26 per cent., and in the second, showing 0·65 per cent. of carbon, the carbon added was 0·40 per cent. These figures and those for the three other steels, which we do not quote, although not sufficient to prove, they at least suggest, according to Sheffield University, that there may be a relation between the carbon gained and the chromium added as metallic chromium in low-carbon steels. Further, the suggestion that carbon is taken from the coke dust in the crucible mixture is not satisfactory, the University add, as no carbon is gained when ferro-chrome alone is used; there is, moreover, only about 6·6 per cent. of coke dust in the crucible mixture. In this connection, the author finds the University's suggestion to the effect that metallic chromium produces the same effect as aluminium and, to a less extent vanadium, in reducing carbon from the furnace gases a very interesting one, and one which is supported by the results of an examination of the steels by Messrs. Stubs; additional confirmation of this is obtained from several makers of stainless steel.

In regard to his experiments, which are illustrated and described in detail in the memoir of which this is a brief review, the author confirms the statement by Moore that the addition of chromium progressively raises the Ac1 point until it is above the Ac2 point, also Moore's other statement to the effect that if the Ac1 is not exceeded, the Ar2 occurs at the same temperature as the Ac2. The author here notes another very interesting feature, one hitherto unrecorded so far as he is aware; a very careful study of the range, has left him quite undecided as to whether there is, or not, an actual absorption of heat at this point Ac2. If there is an absorption, it is only a very minute one. The diagrams in the memoir indicate that in every case where the Ac1 point is above the Ac2 point the differential curves show an abrupt change in direction, and the inverse rate curves show a quicker rate of heating above the Ac2 point than below it. The only logical conclusion, the author adds, is that at the Ac2 point there is an abrupt change in the diffusity of the alloy, and diffusity is a property which depends on both the thermal conductivity and the specific heat. As for the carbon change points on cooling, the fact that they do exist between 700 deg. and 770 deg. C. in all these steels is of the utmost importance since, the author notes, it at once renders Guillet's classification of chromium steels untenable. The author refers to Professor Guillet's researches published in 1903, he shows the area which his own series of steels cover in Professor Guillet's diagram, adding that in every case they were pearlitic when cooled very slowly, and all the steels recalesced between 700 deg. and 770 deg. C. The memoir reproduces curves showing the quenching temperatures, the cracking zone where this existed and the corresponding Brinell numbers, the curves confirming that high-chromium steel may be made austenitic by quenching from a suitable high temperature, and bringing out very clearly the increase in the hardness due to the solution of the excess carbide; the latter effect may be traced to a diminishing extent as the chromium is lowered. All cracks where longitudinal, i.e., in the direction of rolling, and never transversal. The cracking zone was quite independent of the size of the test-piece, being the same for thin micro-sections as for $\frac{1}{16}$-in. cubes; whilst three steels in the form of 1-in. rounds and 5 in. long cracked when quenched from the danger zone, but did not crack when quenched from 20 deg. above it. Before commenting on the point, the author desires to study the volume changes in the steels in question.

The memoir also deals with the analysis of carbides and residues, also with the electric resistivity tests, in regard to which no definite conclusion can as yet be drawn, and with the microscopic examination of the samples which, on the other hand, gives much information upon the nature of the alloys under consideration.

## THE RAILWAYS OF THE UNITED STATES.

BAD as the effects of the war, and the post-war situation, have been on the railways of this country they have in the United States been equally disastrous. Here we have been faced with huge additions to the pay-roll granted under the stress of war conditions—the same has been the case in the United States. Here the war left our railways wofully behind in repairs and maintenance of all kinds—there the railways were handed back after the period of State control in a decrepit condition quite unworthy of their former selves. Here, too, the period of State control and post-war legislation have saddled the railways with heavy expenses connected with regulation, and have involved them in a vast amount of trouble in trying to meet the Government's insatiable appetite for statistics. There the result has been similar, and the clerical staff has had to be so largely increased that the cost to the nation of the information furnished is very unlikely to be offset by any commensurate return. Some idea of what has been involved in this last direction in the United States may be gathered from the facts that the railway clerical staff (counting only employees earning 900 dols. and over per annum) has increased in number practically by 68 per cent. in about five years, while the total paid to this branch in salaries has grown by no less than 224·2 per cent. It is asserted, in view of the traffic handled, and the increase in the price of labour, that the same number of clerks as formerly did all of this class of work which reasonably ought to be imposed on the railways, should be able to do it now, with an increased cost of not more than 100 per cent. Again, as our railways were left to carry on with uneconomically low rates till their prospects as commercial undertakings became most dismal, so in the United States the revision of rates and fares was deferred until the State was called upon to make good very heavy deficits, and when finally rates were raised to a level which bore some relation to the cost of service the shock to the manufacturing community was considerable. Just as here the companies are puzzled, now that they have been handed back by the State, by the problem of how to make their concerns pay with an expenditure which has greatly outgrown revenue, so in the United States the railways are in the position of having to meet interest and other charges out of a margin which is practically non-existent.

The annual statistics prepared by Mr. Slasson Thompson, and published by the Bureau of Railway News and Statistics, Chicago, Ill., U.S.A., give in the latest edition figures for the year ending with December 31, 1921. These statistics for the railways of the United States are always published a long while in advance of the Government returns,

and, though they are not quite so complete as the latter, they are compiled from official figures furnished by all save a few of the smaller companies, and can therefore be taken as a fair guide to the situation. Wherever possible comparison is made with the latest Government figures. Mr. Slasson's figures show that whereas formerly the operating ratio of expenses to revenue for the United States ranged about 64 per cent. to 66 per cent., in 1920 this figure had risen to 94·44 per cent. The increase in expenses between the years 1913 and 1920 amounted to over 3,000,000,000 dols., of which all but a comparatively small portion was due to State management and regulation, and the balance to increased cost of fuel, materials, &c. The entire operating revenues of 1916 did not equal the pay roll of 1920, swollen as it was by Labour Board awards and National Agreements. The absurdity in a large country such as the United States of standardising wages of employees must be manifest to anyone who has moved about the world at all, and the burden these impose on systems in some areas, is enhanced by the introduction of the 8-hour day, and union regulations. With regard to the latter the case may be instanced of the renewal of a blast pipe nozzle—a job formerly done by one man, but now requiring no less than six.

With these restrictions go the very heavy rates for overtime. The usual excuse put forward by labour for penalising overtime is that the employer should be made to take on sufficient hands for his work, and so decrease unemployment. In the United States things do not seem to work out quite this way on the railways, where the men have latterly been found to put forth much below their full effort during the ordinary day, in order to have to work overtime at the enhanced rates afterwards. The result of this policy, and of the exorbitant wages awards, has been that railway companies have, since the war, curtailed much of the work in their own shops, and have arranged for repairs to stock to be done by contract by firms who do not have to work under such onerous conditions. This may be good for the contractors, but it will not be good for the country if its great railway industry is crippled beyond repair.

At the close of 1920 the miles of railway owned amounted to 252,500, much the same as in 1914, though in the meantime the figure has been up to 254,734, the difference being accounted for largely by lines required for war purposes in connection with industry, camps, &c. The cost of the latter, by the way, has, under Government ruling, been charged to capital account of the railways, as has also a large sum spent on what were properly inadequate replacements of locomotives and stock. The effect of the first charge has been permanently to increase the amount required to meet capital charges, though the railways have ceased to derive any benefit from the expenditure since the end of the war. The question of rolling-stock we revert to below.

During the last four years close upon 4,000 miles have been abandoned as unremunerative, and construction has been of a restricted character. In fact, only some 314 miles of lines are reported as being built in 1920, a figure between one-tenth and one-twentieth of what was customary before the war, and even less than half that for 1919. The stagnation is brought out by the fact that in 1910 there were 382 people per mile of railway, whereas in 1920 there were 418, while the mileage has decreased from 8·57 per 100 sq. miles of territory in 1917, to 8·49 in 1920. In addition to the abandonment of war lines, the companies are now facing competition on short distance traffic. Although the steam roads do not appear as yet to have felt this so seriously that traffic has been abandoned, the trolley roads are undoubtedly being hit by automobile competition. In fact, these systems have definitely withdrawn from traffic on some 275 miles of line in recent years, owing to the large use made of low-priced automobiles.

It is computed that the railways of the United States require annually in the form of replacements, to take the place of stock which must be scrapped, something like 3,000 locomotives, 2,000 passenger cars, and 100,000 freight cars. These figures were well maintained before the war; in boom years when trade was expanding they were more than doubled. In contrast, the year 1920 showed only 2,022 locomotives built, and 1,272 new passenger cars, and 60,955 freight cars. Against the 2,022 locomotives must be placed 1,334 scrapped that year, though every effort was made to retain in service anything that would work, to help make up for the lee-way of the war period. It is estimated that during the whole period of State control stock to the value of 381,000,000 dols. was purchased by the railways, mostly consisting of 2,000 locomotives and 100,000 freight cars. This sum has been permanently charged to capital, the Government having refused to meet what would normally have been a revenue charge, as the expenditure was far less than that required to keep the stock up to an effective standard. In passenger stock a decrease is shown in passenger coaches, dining cars, &c., but an increase in baggage cars, as compared with 1918, the latter being due largely to fragile mail matter. As regards goods stock the number of flat cars has decreased steadily ever since 1908, while the number of box-cars and of coals cars in service was higher in December, 1920, than ever before. Stock cars also showed a decline. In addition to the increase in numbers has to be taken into account the increase in capacity. This has improved in the case of box cars from an average of 27 tons (short) in 1902, to 37·1 tons in 1920. Coal cars have also largely increased in size, viz., from an average of 31 tons in 1902, to 47·4 tons in 1920. This is of course due to the introduction of very large-capacity cars capable of carrying 80-ton and 100-ton loads, to which we have referred on previous occasions.

The sudden wave of depression which has swept over the world, has had the momentary consequence of a car surplus which in February last was calculated at 300,000 cars, and was subsequently increased, but since has improved. This surplus contrasts with a serious shortage calculated at about 150,000 a year previously. It is estimated that about half the idle cars have been standing for repairs long overdue, but the companies owing to the drain on their resources, have lacked the means of putting them in repair during the depression ready for a revival of business.

We have already referred to matters connected with labour. Here are some instructive figures: In 1916 the number of employees per 100 miles of line was 681; in 1920 this figure had increased to 826. The hours worked numbered in 1916, 5,097,538,000, compared with 5,588,568,000 in 1920, but the pay totalled 3,763,772,000 dols. in 1920 compared with 1,511,728,000 dols. in 1916. If we compare 1920 with 1917 we find that in the latter year it took 17 per cent. more employees to give less than 1 per cent. more hours of service. It is noteworthy that while the average yearly pay per man increased by 110 per cent. in the four years 1916–20, the hourly pay increased by 140 per cent., which shows the influence the heavy overtime rates have on operating expenses.

The net capitalisation, excluding the compulsory capital expenditure, most if not all of which would normally have been met out of revenue, of 250,834 miles of line in 1920 stood at rather more than 18,086,000,000 dols., or 72,106 dols. per mile, compared with pre-war figures of about 67,000 dols. per mile. The service rendered is estimated at 47,276,131,000 passenger-miles and 411,151,320,000 ton-miles in 1920. Both these figures exceed previous years. Increases in rates have resulted in very much larger revenues than formerly for comparatively small increases in traffic. The revenue, from operation amounted to 6,300,000,000 dols., but the total expenses without taking into account interest liabilities, amounted to over 6,272,000,000 dols.; this resulted in the railways being faced by a deficit of about 622,000,000 dols., taking interest and sinking fund into account. Naturally most operating expenses show increases. Between 1917 and 1920 the proportion of transportation expenses to gross earnings rose from 37·85 per cent. to 46·81 per cent.; maintenance of equipment showed that 17 per cent. increased to 25·6 per cent.; maintenance of way 11·08 per cent. to 16·7 per cent., and so on. Classified on a different basis it is seen that pay to employees represented 43·71 per cent. of the gross earnings in 1917 but 59·74 per cent. in 1920, while fuel for locomotives only increased from 9·85 per cent. to 10·95 per cent. Betterments and reserves have decreased, and dividends as already noted disappeared.

## THE PHYSICAL AND OPTICAL SOCIETIES' EXHIBITION.

THE annual exhibition of apparatus arranged by the Physical and Optical Societies was held at the Imperial College of Science and Technology, South Kensington, on Wednesday and Thursday of this week. Upwards of 50 firms exhibited instruments and appliances, with many of which demonstrations were given at intervals. During the course of the exhibition discourses were given by Mr. A. A. Campbell Swinton on the Johnsen-Rahbek electrostatic telephone, the principle of which were fully explained in our columns on page 685 of Vol. cxi. Other lectures dealing with radium and its applications in peace and war, and with the employment of coarse wire gratings in astronomy, were delivered by Mr. F. Harrison Glew and Sir Frank W. Dyson, Astronomer Royal, respectively. The demands upon our space, however, are such that we must confine our attention

*Fig. 1.*

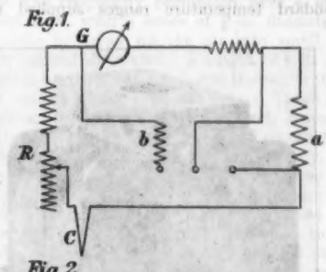
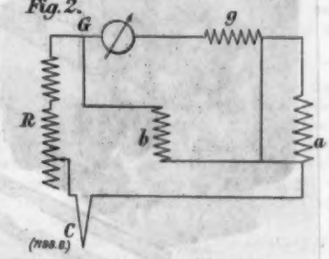



*Fig. 2.*




(*nos. 2*)

to the exhibits, and of these we can only refer to such as possess some novel features likely to be of general interest to engineers.

One of the most interesting exhibits of the Cambridge and Paul Instrument Company, Limited, whose address is 45, Grosvenor-place, S.W. 1, was a new form of thermocouple pyrometer which enables a simple and robust direct deflection indicator to be used while at the same time every source of error is compensated for. These errors include changes in the sensitivity of the galvanometer and of the resistance of the thermo couple and other parts of the circuit, such changes being almost entirely due to temperature variations. The accompanying diagrams, Figs. 1 and 2, show the connections, which are arranged as in Fig. 1 when the instrument is in normal use, and are altered by means of a switch to the arrangement indicated in Fig. 2 for the purpose of checking the adjustments. In the diagrams, G is the indicating galvanometer, C the thermo-couple, R an adjustable rheostat, and $a$ and $b$ are two manganin resistances. In use, the rheostat R is adjusted so that when the change-over switch is operated, the galvanometer deflection does not alter, and when this is the case accurate readings of temperature are obtained. It is, of course, only necessary to make the adjustment occasionally as conditions change. In designing the instrument it is necessary to choose values for the resistances $a$ and $b$ to suit the galvanometer resistance, and also to know the temperature change of the current sensitivity $\beta$ and of the resistance $\alpha$ of the galvanometer. The two conditions to be complied with are that $\frac{a}{\beta} = \frac{g + r + a}{r - g}$ and that $a\ b = r\ g$, where $r$ is the average resistance of the whole thermo-couple circuit, excluding the resistance $a$ and the galvanometer resistance $g$. These

conditions are quite easy to comply with in practice, and the arrangement has the great practical advantage that it is unnecessary to employ high resistance circuits or very sensitive galvanometers of high resistance. Accurate readings are ensured with a low resistance galvanometer having strong control springs, provided there is no uncertainty as to the constancy and chemical composition of the couple.

The company also showed a pyrometer of the disappearing-filament type, designed by Dr. Ezer Griffiths, this comprising a small electric lamp in series with an ammeter and a rheostat, the operating current being supplied by a 2-volt accumulator. In use, the body of which it is required to measure the temperature is observed through the eyepiece of the instrument, in which the lamp filament is also visible, and adjusts the current until the brightness of the filament is exactly equal to that of the hot body. The current is then a measure of the temperature, and the latter can be read directly by suitably graduating the ammeter, which is of the moving-coil type and is damped sufficiently to make the movement of the pointer dead beat. The standard temperature ranges supplied are gives a deflection of 10 mm. at a frequency of 800 cycles per second, a deflection of 20 mm. at 550 cycles and a deflection of 30 mm. at 323 cycles.

Of more direct interest to engineers is a portable $CO_2$ and temperature indicator in which the catharometer and filter are enclosed in a small case provided with a handle for carrying. To use the instrument it is only necessary to connect a pipe to the flue and to connect the leads from a thermocouple to terminals in the case. The flue gases are then drawn through the instrument by means of a rubber bulb and the percentage of $CO_2$ is indicated electrically by the deflection of a galvanometer. By operating a switch, the same galvanometer gives the temperature of the gases by means of the thermocouple.

Other exhibits of the firm include the well-known Shimizu-Wilson cloud condensation apparatus for rendering visible the tracks of $\alpha$ particles and $\beta$ particles, Fawssetts' apparatus for measuring alternating current power at distant points of a distribution system, hydrogen-ion apparatus for determining accurately the acidity or alkalinity of solutions, and a device for automatically regulating the temperature of electric furnaces. The

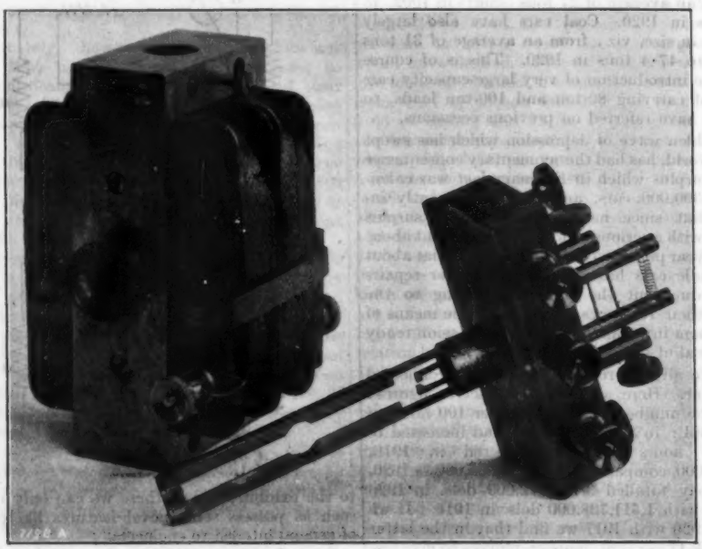


FIG. 3. EINTHOVEN STRING GALVANOMETER; MESSRS. THE CAMBRIDGE AND PAUL INSTRUMENT COMPANY, LIMITED, LONDON.

700 deg. to 1,400 deg. C., and 900 deg. C. to 2,000 deg. C., and we understand that persons without any previous experience in the use of the instrument can easily obtain temperature readings with an error of less than 1 per cent. We may add that the lamps of these pyrometers are never used at their maximum brilliancy, and that they are also specially aged by the makers to ensure constancy over very considerable working periods.

Another interesting exhibit by the same firm is illustrated in Fig. 3. This is a simple form of Einthoven string galvanometer similar to that developed by Professor Salomonson. In this the "strings" are two copper fibres, usually 0·01 in. in diameter, and the arrangements are such that a magnification of 40 is obtained at a working distance of 80 cm., which is very convenient for photographic work. The instrument can be used either alone or in conjunction with the larger Einthoven galvanometer made by the firm and having a silvered glass fibre, the optical system of the smaller instrument then forming the eyepiece of the larger one. In use, the metal fibre of the former are arranged to be in the same plane as the image of the silvered glass fibres formed by the objective of the larger galvanometer, so that all the fibres can be focussed together on the screen. It is thus possible to take an electro-cardiogram, a phono-cardiogram and a pulse tracing simultaneously on the same plate. With a magnification of 40 and a current of 0·01 ampere, the instrument illustrated first-mentioned apparatus has already been fully described in our columns, and with the others we hope to deal more fully on a future occasion.

The exhibit of Messrs. Adam Hilger, Limited, 75A, Camden-road, N.W. 1, consisted mainly of apparatus for studying the physical properties of glass. A spectrometer for measuring absorption in the red and infra red regions of the spectrum was shown, together with a quartz spectrograph for similar work in the violet and ultraviolet. For quantitative measurements of absorption in the latter regions, a sector photometer was exhibited together with curves obtained by the use of this instrument. The Nutting photometer and wave-length spectrometer for measuring absorptions in the visible region of the spectrum, such as those of coloured glasses, was also shown, and its use demonstrated by showing the shift of the absorption bands of didymium glass at high temperatures. The Hilger interferometer was used to show the heterogeneity of a block of optical glass due to imperfect mixing, and also the variations in the refractive index at the surface of a piece of glass taken from the top of the melting pot. Another interesting demonstration to show the effect of imperfect annealing in causing double refraction was also made, and the effect of rapid cooling on the refractive index was demonstrated with the Pulfrich refractometer. Most of the above-mentioned instruments have, however, been dealt with in our columns on previous occasions, as also has the firm's apparatus for controlling the annealing of glass, which was shown at the exhibition. The most recent developments of the latter apparatus were described by Mr. F. Twyman in a paper read in December last before the Society of Glass Technology, an abstract of which appeared on page 854 of our last volume. We hope to deal more fully with this apparatus in a subsequent article, but in the meantime we may refer our readers to the above-mentioned source for further particulars.

An interesting instrument included, we believe, for the first time in Messrs. Hilger's exhibit, was their optical sonometer, in which the form of a sound wave is recorded photographically. In this instrument, light from a "Pointolite" lamp is directed on to the gilded surface of an exceedingly light diaphragm, on which the sound wave impinges, and a spot of light reflected from the diaphragm is thrown on to a moving photographic film, which may be either an ordinary kinematograph film or a piece of sensitised paper. The film, in either case, is enclosed in a light-tight box which can easily be removed to a dark room for developing or recharging. The most novel and interesting feature of the instrument is, however, the nature of the diaphragm, which consists of a celluloid film, $\frac{3}{8}$ in. in diameter, and only a fraction of a light-wave length in thickness. The gold coating necessary to form a reflecting surface on the celluloid is applied by cathodic deposition. It is interesting to note that the instrument was originally designed for investigating the noises produced by geared turbines.

*(To be continued.)*

## NOTES.

### UNITED STATES PATENT PRACTICE.

AMONG the Patent Office decisions that are referred to from time to time in the prosecution of cases before the United States Patent Office attention has recently been drawn to one known as *ex parte* Tschirner, which may well be noted by inventors because it deals with a case in which two separate applications are required according to United States practice, whereas one would suffice in this country. Thus, assume an inventor has obtained a single British patent and was under the impression that he could obtain the same in the United States, he would find that he would not be allowed to do so in one application with one set of fees. The matter in question relates to: (*a*) A composition, and (*b*) a process of using it. The case is fully given in the American *Official Gazette*, vol. xcvii, page 187. The patent application in question contained claims to a composition to be used for destroying dental nerves, and during the prosecution claims were added to the process of using this composition. As a matter of procedure, the examiner rejected the process claims, but it appears that even had they been introduced at an earlier stage he would not have accepted them in a single application with the composition claims because as far as could be shown no authority warrants the retention in one case of claims to a composition and the process of using it. The matter was upheld by the Commissioner of Patents on Appeal from the examiner's decision, for in his view a composition and a process of using it are independent inventions. At the same time he mentioned that a composition and the process by which it is produced may in some instances be so closely related as to be properly claimed in one application, so that this case, in addition to constituting a negative authority against the retention of claims to a composition and the process of using it, constitutes a positive authority for the filing of claims to a composition and the process of producing it in certain cases in one patent application. In Great Britain, generally speaking, claims both to a process of making and a process of using a product could be obtained, but in this connection one must bear in mind the provision of Section 11 of the recent Patents and Designs Act, 1919, which provides that in the case of inventions relating to substances prepared or produced by chemical processes or intended for food or medicine the specification shall not include claims for the substance itself except when prepared or produced by the special methods or processes of manufacture described and claimed or by their obvious chemical equivalents.

# LITERATURE.

*The Work of the Royal Engineers in the European War, 1914–19. Water Supply.* Part I. *General Development of Organisation Plant and Works.* Part II. *Operations.* Published by the Secretary, R.E. Institute, Chatham. Chatham: W. and J. MacKay and Co., Limited. [Price 25s.]

THE difficulties of procuring the adequate amount of water required by men and animals in actual war operations have in the past tended to confine large armies to the proximity of rivers. With modern appliances, this restriction of movement becomes less imperative, but the task of collection and distribution is rendered more arduous and the responsibilities of those charged with the duties more onerous, as the distance from the supply grows greater. For men can, and will, fight doggedly in spite of lack of ammunition, military ardour will not be damped by a shortage of food for several days, but both men and animals will break down in a few hours and lose their spirit, condition, and powers of resistance, unless they can obtain water in sufficient quantity and of the necessary purity. The amount required will vary according to climate and other circumstances, but in the recent war, the aim was to give every man on the march a minimum of one-third gallon per day, and when stationary, 1 gallon. For horses the minima was to be 2 gallons per head on the march, and 3 gallons when resting. Since collecting grounds vary and enemy operations hinder movement, the fulfilment of this task involved great difficulties, and the study of the methods by which it was achieved is as necessary to those engaged in the work of army service and organisation, as are the details of the strategy and tactics by which great victories are won. This book, presenting a plain statement of what had to be done and how it was accomplished, should bring home to all some better appreciation of the work that falls to a portion of the army usually considered non-combatant.

This report deals only with the operations connected with the water supplied to the British Expeditionary Force in Flanders, mainly along the Bethune-Ypres line, and subsequently in North-West France, in the neighbourhood of Arras and the Somme. In respect of water supply the two districts offer a vivid contrast. In the former, surface water was abundant, and deep wells were impossible, for the chalk was not water-bearing, and below the chalk the water was unfit for drinking and generally impregnated with minerals. Shallow wells and canal water could be relied upon, but the water would be liable to contamination, and extensive purifying works would be needed. On the other hand, in France, the army was stationed upon, and, in advancing, had to cross, a practically waterless plateau, some 15 miles in breadth. The line actually came to rest at about the middle of this expanse, but this brought no relef to the water service department. Boring and well-sinking had to be carried out extensively, and the work was made extremely onerous when preparations were being made for an advance. The utmost secrecy had to be preserved, and yet provision had to be made for the needs of the troops as they occupied more advanced posts.

In the early days of the campaign, the British force was stationed on the Belgian frontier and was naturally provided with an equipment adapted to collect water from or near the surface, and movements were controlled by the necessity of locating animals at stations where surface water was available. Enlarged mobility was effected in course of time, but the experience gained by the staff on the water-bearing superficial strata of Flanders was of little use on the dry plateau of France, that demanded boring apparatus and other methods. Nevertheless at the close of hostilities when men and animals had greatly increased in number, the water supply organisation and equipment had so improved, that concentrations of unexampled density could be effected, and operations successfully carried out at short notice in any area, and at the points most desirable for strategical reasons without fear of water shortage. This result was attained by organisation, effective in design and prompt in execution. It involved a large increase in mechanical plant, and the employment of semi-permanent and extensive systems of supply, with head works and pipe lines, the use of mechanical transport on a large scale for the carriage of water, and the installation of chemical and mechanical systems for the filtration and purification of water. Sea-going barges were requisitioned from the Thames for this latter work. They were fitted up with steel plate tanks and special low-lift centrifugal pumps. In France, if purification was less necessary, the extensive use of boring plant to render available deep-seated sources of water supply increased the work very materially, but if the labour was onerous it was justified by its success.

It will give some idea of the magnitude of the effort that had to be made to meet pressing requirements if we cite the main features of the arrangement that was carried out in anticipation of a big offensive at Vimy Ridge, where surface water was utterly unattainable and extensive pipe systems had to be planned. A concentration of 80,000 men and 36,000 horses was contemplated, and allowing 5 gallons a day per man and 10 gallons per horse, 760,000 gallons per day was needed. To ensure this delivery, 22 engines and 24 pumping stations were completed, 45 miles of pipe were laid, 16 reservoirs of various capacities were constructed, and the water distributed in sufficient quantities to the necessary horse watering points, and to cart-filling and bottle-filling points. In addition a 50,000-gallon reservoir was excavated with 25 ft. of head cover, with additional accommodation for two engines, pump engine crews, repair shops and stores. We are told of similar activity on other fronts, for instance between Arras and the La Bassée Canal, 58 pumping stations were erected, capable of delivering 155,000 gallons of water per hour, but there is no necessity to multiply such instances.

The two most salient features in the general scheme of water supply throughout the military operations were the purification of the water in Belgium and the work of well-boring and water pumping in France. In the former case, not only did the special plant erected furnish examples for similar work in Mesopotamia, but the efficiency was unique and "as far as is known similar purification had never been attempted previously, either in peace or war." The filtration barges were supplied with excellently-equipped laboratories in charge of fully-qualified chemical officers, who exercised control over the whole process of purification, taking samples at every stage and were prepared to de-poison the water if, as reported, arsenic was put into it. Not only arsenic was feared, for their equipment provided for the treatment of practically every poison which it was thought possible the enemy might introduce into the waterways. A conspicuous example of the work of purification is furnished by the scheme successfully adopted at Haringhe, designed to supply 200,000 gallons per day of filtered and chlorinated water from the Yser, withdrawn under the ordinary conditions of the river. It comprised the construction of a settling tank of about 100,000 gallons capacity, and a clear water tank for storage of the same size: two pre-filters (30 ft. by 20 ft.) of shingle, arranged in parallel, and two similar filters of gravel and sand of three times the area. In the collecting tank it was expected to obtain a certain amount of preliminary sedimentation, and a clearer water would pass to the gravel roughing filters, which it was arranged should be chlorinated by an automatic feed of chloride of lime, before passing into the storage tank. Actually if was found that the crude river water, containing a variable and considerable amount of finely-divided suspended matter, together with organic matter, rapidly choked the sand filters. Neither did the sand filters remove the colour or the taste from a water so highly contaminated as that of the River Yser, and it was decided to add preliminary sedimentation tanks, using alumino ferric as a coagulent to assist the sand filtration. With cleaner and more finely graded sand and gravel, the scheme was successful. Towards the end of the war a form of tube strainer, designed to prevent the fine sands met with in boring operations percolating through the filters, was introduced, and this apparatus had the effect of increasing the delivery of clear water by 50 per cent. The strainer consisted of an octagonal column of rods, kept in place by steel rings, wound round on the outside with copper wire. The spacing between the wires was important, for it was found that the efficacy of the filter depended mainly on adapting the winding of the wire armature to the particular size of the grains of sand encountered.

In the boring and pumping operations in the chalk area, a conspicuous feature was the success of the air-lift pump, an apparatus, however, that was not adopted outside France and Flanders. Without this addition, the maximum quantity raised from a 6-in. borehole averaged 3,000 gallons per hour, but in suitably chosen positions, with the air lift the output rose to 6,000 gallons and 10,000 gallons per hour. Compressors with duties varying from 100 cub. ft. to 145 cub. ft. of free air per minute were of various forms and driven in combination with petrol engines, equally various in make. The arrangement of piping in the borehole was dependent on the size of the compressor. Usually in 6-in. bore holes, a 4-in. rising main was used with a 1-in. diameter internal air pipe. The air pipe was frequently perforated over a length of about 2 ft., with a series of $\frac{1}{8}$ in. diameter holes, in order to break up the air into small bubbles as it entered the water. A length of 8 ft. or 10 ft. of plain air pipe was left below the perforators, and the bottom of the pipe left open. There were no working parts below ground level, consequently valve and plunger trouble was eliminated. On a sudden demand for water on emergency, a compressor could be mounted on a 5-ton lorry chassis, driven to the spot where the shortage occurred, the 1-in. air pipe connected up and worked till the reservoirs were full, and then moved on to another station. In the general British advance at the end of the war the extensive and successful use of the mobile compressor frequently saved the situation and prevented any shortage of water.

A pump of French make, known as the "*Chaine Helice*," was found very useful. The main part consists of a light chain running over a pulley at the top and round a counterweight pulley at the bottom, which was immersed in the water, this chain carrying wire helices at intervals. When the chain was drawn through the water, it brought water to the surface, which was thrown off by centrifugal force as the chain passed the top pulley, and was caught in a collecting box. The delivery was about 600 gallons to 700 gallons per hour.

It is impossible to do justice to the mass of detail collected or to the excellent photographs and maps that accompany the report. The preparation must have entailed long and careful work, but it was necessary to bring home to the public, the extent of the operations undertaken by the Water Supply Department, and to make available for future guidance the experience gained under the severe conditions of actual service.

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*Aussergewöhnliche Druck-und Temperatur-steigerungen bei Dieselmotoren.* By DR. ING. R. COLELL. Berlin: Julius Springer. [Price 20 marks.]

WITH the Diesel engine proper—disregarding the so-called semi-Diesel engines of the surface-ignition and hot-bulb types—the maximum pressure is not supposed greatly to exceed the compression pressure, *i.e.*, explosive effects should be absent. Failures of Diesel engines indicate, however, that the pressures and temperatures sometimes become excessive under ordinary running conditions. In the pamphlet of 70 pages before us Dr. R. Colell discusses the causes of such "Extraordinary Rises of Pressure and Temperature in Diesel Motors," as well as the measures to be adopted to obviate these troubles. He confines himself to 4-cycle engines and deals particularly with fuel valves of the needle type.

The oil is atomised through the fuel valve and is injected into the air of the cylinder which will be at a temperature (of about 1,200 deg. Fahr. or above) corresponding to the compression pressure adopted, and this temperature will be higher than the ignition temperature of the oil-spray. As long as oil drops and air only are present there will be, Dr. Colell states, a gradual fuel combustion drop by drop rather than an explosion of a vapour mixture. When, however, an explosive mixture has been

compressed by a premature admission of oil into the cylinder, excessive pressures may arise. The most common cause of such an occurrence he finds in the sticking of the needle of the fuel valve. The spring of this valve has to overcome the pressure of the injection blast which may be as much as 80 atmospheres, and the friction due to the tightening up of the stuffing box of the needle, which is generally packed with lead shavings or with soft metal rings, is not always effected with all the care it demands. Should the needle stick, the following expansion and exhaust strokes will not be much affected, nor will the first two strokes of the next cycle. But the fuel pump will meanwhile have started on a new feed stroke, and under certain conditions a mixture of vapour and air may be present during the compression stroke. This mixture will have a lower ignition temperature than the normal air-oil mixture, and pre-ignition may occur. Such an explosive mixture may also be formed should oil collect on the top of the piston during an examination of the needle valve, or when lubricating oil has found its way into the cylinder. All these causes will favour pre-ignition.

What the ignition temperatures in internal combustion engines actually amount to is uncertain. Dr. Colell has attempted to determine the temperatures by introducing a definite amount of fuel into a cylinder and tracing on the indicator diagram the point at which ignition sets in. He only claims for his measurements such accuracy as may be expected in an engineering testing laboratory, but he has had considerable experience in testing Diesel engines.

Dr. Colell, late of the Daimler Works, is now technical director of the Automobile Fabrik Stoewer-Werks, of Stettin. The experiments were made with a marine Diesel motor developing 500 h.p. at 400 r.p.m.; each of the six cylinders has a piston displacement of 33·5 litres and is provided with a relief valve of 20 mm. internal diameter with a maximum lift of 5 mm., loaded to resist a pressure of 60 atmospheres. The special indicator was supplied by the firm of H. Maihak, of Hamburg. No particulars of these indicators are given. His calculations suggest that pre-ignition would under certain conditions, commence at a pressure of 12 atmospheres and that the cylinder pressure would then rise to 113 atmospheres. In practice maximum pressures of 140 atmosphere would be possible in cylinders from which the gases cannot escape, especially when for some reason more than the ordinary quantum of oil is admitted. Many Diesel engines are not provided with a relief valve. Even when they are, Colell maintains that the internal cylinder pressure may arise far above the load of the valve.

In experimenting on the influence of a sticking fuel needle-valve upon the internal pressure, Dr. Colell opened the indicator cock after having run the motor for about an hour and then screwed down the fuel valve packing until the needle seized. The pressure in the cylinder consequently rose and each operation of the relief valve was accompanied by a loud report. The injection pressure was, in these experiments, regulated to 75 atmospheres, and a non-return valve as well as a safety-valve set to 90 atmospheres, were inserted in the pipe leading to the fuel valve. The experiments gave a maximum internal pressure of 110 atmospheres, in agreement with the author's calculations. It is customary in Germany to fix the relief-valve load at 60 atmospheres. Dr. Colell himself would not recommend a higher load on this valve, since in that case the cylinders and parts of the motor would have to be made much stronger than at present to meet the higher internal pressures likely to arise. On the other hand a lower relief pressure than 60 atmospheres might be troublesome in starting up the engine and, on board ship, in reversing it. But Dr. Colell would raise the pressure under which the engines are to be tested. The Bureau Veritas requires, for marine motors, a test pressure of 1·75 times the compression pressure, that is to say, a test pressure of about 58 atmospheres, being guided apparently by the opinion that the internal pressure cannot arise above the pressure at which the relief valve will blow off.

In his further considerations, Dr. Colell deals with the stresses and strains due to temperature and pressure, referring in the first instance to the fortunately not frequent cases in which injection pipes burst during ordinary running, though the material seems to be sound. He points out that normally there will be a relatively large fall of pressure between the fuel valve and the compression space. That the flame does not strike back into the atomiser he ascribes to the expansion which the air undergoes in the nozzle plates. When the injection pressure is 70 atmospheres and the compression pressure 40 atmospheres, the fall of pressure gradient should cause the air to cool below freezing point. In one of his experiments, Dr. Colell cut out the compressor while the motor was running. When the injection pressure had diminished from 60 atmospheres down to 38 atmospheres, misfires began to occur and the exhaust, so far invisible, turned dark. Yet he was able to run his motor for another hour, and there was no striking back of the flame, as long as the injection pressure did not fall below the compression pressure. An explosive wave, well known to occur in long tubes, can hardly develop in the cylinder of an internal combustion engine, though it might conceivably do so in the piping. Nevertheless the temperature in the cylinders may rise very high. Dr. Colell observed in several cases that atomiser plates made of delta metal (melting at 950 deg. C.) had fused, the solidified drops of metal being found in the atomiser.

Parts of the engine may therefore have to bear temperatures approaching 1,000 deg. C., at internal pressures of 140 atmospheres. In the designs of these engines the temperature stresses are allowed for, but the formulæ extant apply only to atmospheric pressures, and there are hardly any data admitting of determining in how far these figures have to be modified to allow for the effect of high pressures. Basing himself upon the expression for the temperature stresses—radial, tangential and axial—at atmospheric pressure, which H. Lorenz gave in his "Lehrbuch der Technischen Physik," of 1913, Dr. Colell deduces equations for the influence of the internal pressure upon these three components. He finds that the stress maxima due to both pressure and temperature, are proportional, both to the temperature difference between the inner and the outer cylinder walls (of radii $r_1$ and $r_2$) and to the internal pressure, and that they depend upon the ratio of the radii $r_2 , r_1$, but not upon the absolute temperatures, nor upon the magnitudes of the radii. The stresses and strains would, of course, not all be additive. With a temperature difference of 10 deg. C. between the inner and outer walls, the tension produced by an internal pressure of 75 atmospheres, will, at the inner wall of the cylinder, be balanced by the compression due to the thermal stress; whilst on the exterior of the cylinder the tension would be raised by 120 per cent. owing to the addition of the thermal stresses.

In drawing his conclusions Dr. Colell does not overlook the influence of temperature upon the strength of the materials. In the case of copper, the strength rapidly decreases with rising temperature. In the case of mild steel the elongation has, according to Bach and Baumann, 1915, its minimum at 180 deg. C. but increases again as the temperature rises, while the tensile strength increases up to about 300 deg. C. and then diminishes, remaining at 60 per cent. of its value at 20 deg. C. Cast iron, it is stated, is little influenced by temperature; its tensile strength at 500 deg. C. is within 76 per cent. of its value at ordinary temperatures. In view of these facts, Dr. Colell concludes that the injection pipe and the fuel valve casing in which explosive waves might possibly be set up, need not be made strong enough to resist such exceptional contingencies. He would test cast iron, so far as applicable to a pressure of 200 atmospheres and seamless mild steel pipes, to a pressure of 400 atmospheres. He does not pretend to have supplied more than an additional link in the long chain of problems which will have to be solved before the full theory of the Diesel engine can be developed. He certainly deserves credit, however, for having elucidated some points connected with the working of Diesel engines.

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*Gasoline and other Motor Fuels.* By CARLETON ELLIS and JOSEPH V. MEIGS. London: Constable and Co., Limited. [Price 60*s.* net.]

THERE is now an ample stock of books on motor fuels at the disposal of various inquirers. Messrs. Carleton Ellis and Meigs tell us that they have been anxious to strike a balance between the theoretical and the practical in the description of the motor fuel industry. How they understand that we see from the remark that the volume should be of considerable value to the inventor and patent attorney, while the business man and the banker interested in developing and promoting the methods advanced for the production of motor fuel would find the book one of easy reference. The claims are justified, but they hardly constitute a combination of the theoretical and practical. The inventor, of course, needs guidance and, on occasions, a warning, when he is trespassing. We doubt that the promoter is given to the study of text books; he relies on expert advice and sometimes pays dearly for it, we are afraid. The engineer has other interests, and the rather indefinite title "Gasoline and other Motor Fuels" does not specify the aim of the authors.

Mr. Carleton Ellis, of Montclair, New Jersey, is a consulting chemist, well-known as author of books on oils and their hydrogenation and on catalysis. Mr. J. Meigs, of Malden, Massachusetts, is chief chemist to the Massachusetts Oil Refining Company. Most of the experts, whose assistance they acknowledge, are oil technologists rather than engineers, and we do not mean the statement, that the volume is not compiled especially for engineers, in any critical sense. Even the general reader, however, hardly wants 20 chapters, out of 27, nearly half the book, on oil cracking processes, some of which did not get beyond the laboratory stage, and when a process is described in detail although it was practically shelved several years ago, the reader expects to be told so in a new publication. The authors anticipate criticism for their inclusion in their volume of so large a number of processes described only in the patent literature. That criticism may be made, although we admit that failures are instructive.

Though gasoline is a mixed fuel, not easily defined, it seems a little odd to open the volume with a chapter on Mixed Fuels. One looks for information on the main constituents in the first instance. Something of this is given in the second chapter on the Testing of Motor Fuels, which is satisfactory from the general standpoint, but weak from the engineer's point of view. We find more information on the uses and advantages of various motor fuels in the last chapters of the volume, on Benzol and on Alcohol, and also on Shale as a Source of Motor Fuel and on the Pyrogenetic Treatment of Asphalt. The bulk of the 709 pages is taken up by Gasoline and Oil Refinery and by the already mentioned chapters on Cracking which alone cover 300 pages. The appendix of 60 pages is largely statistical, and the production figures, comprising those on Coke Ovens, are almost limited to the United States.

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## BOOKS RECEIVED.

*Brassey's Naval and Shipping Annual*, 1921–22. Edited by ALEXANDER RICHARDSON and ARCHIBALD HURD. London: William Clowes and Sons, Limited. [Price 25*s.* net.]

*Pattern-Making.* By W. ROLAND NEEDHAM. London, Glasgow and Bombay: Blackie and Son, Limited. [Price 2*s.* 6*d.* net.]

*Oils, Fats and Fuels.* By THOMAS HULL. London, Glasgow and Bombay: Blackie and Son, Limited. [Price 3*s.* 6*d.* net.]

*Die Saugstrahlturbine.* Von Dr. HANS BAUDISCH. Leipzig und Wein: Franz Deuticke. [Price 10 marks.]

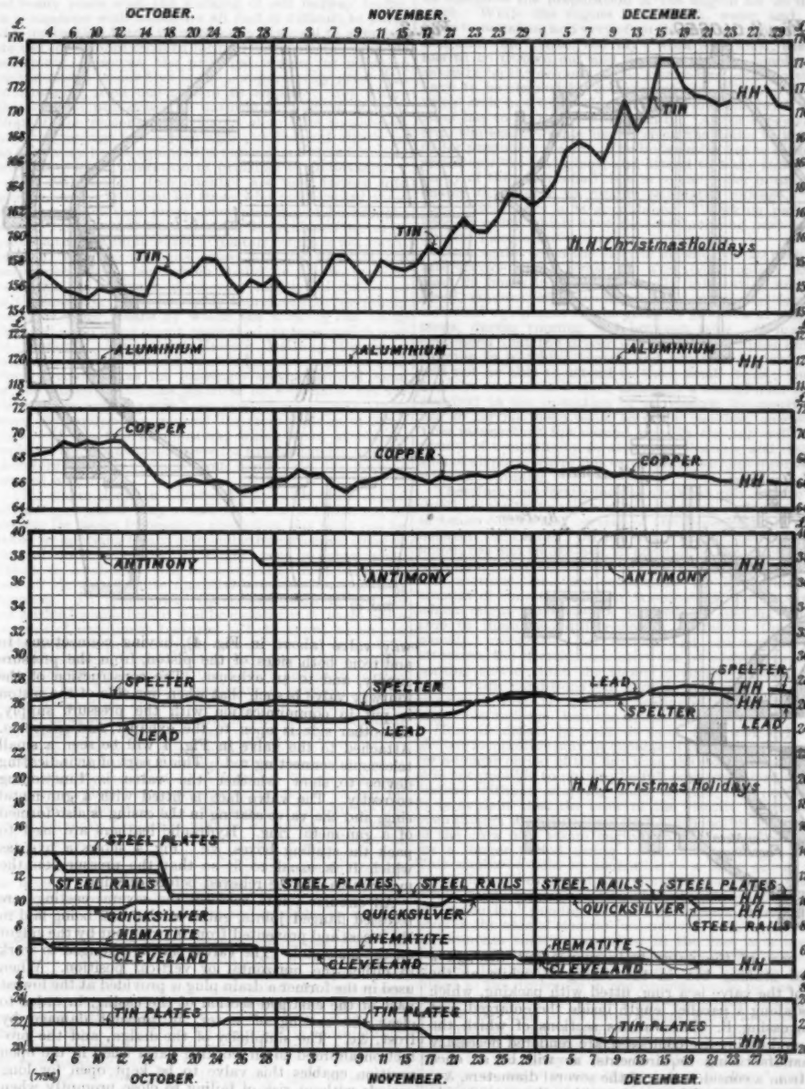
*Rays of Positive Electricity and their Application to Chemical Analysis.* By Sir J. J. THOMSON, O.M., F.R.S. Second edition. London, New York, Bombay and Madras: Longmans, Green and Co. [Price 16*s.* net.]

*Calvert's Mechanics' Almanack*, 1922. Edited by FRANK NASMITH and JAMES MCLACHLAN. Manchester: John Heywood, Limited. [Price 6*d.* net.]

*Department of Overseas Trade. Report on the Financial and Economic Conditions of the Argentine Republic, September*, 1921. By H. O. CHALKLEY. London, Manchester, Cardiff and Edinburgh: His Majesty's Stationery Office. [Price 1*s.* 9*d.* net.]

## DIAGRAMS OF THREE MONTHS' FLUCTUATIONS IN PRICES OF METALS.

*(Specially Compiled from Official Reports of London Metal Markets.)*




NOTE.—In the diagrams the figures plotted for tin and copper are the official closing cash quotations of the London Metal Exchange for fine "foreign" and "standard" metal respectively. The prices shown for lead are for English metal, whilst those for spelter are for American metal. Middlesbrough prices are plotted for steel plates and rails, and also for hematite and Cleveland pig-iron. The prices given, in the case of steel plates are for ship, bridge and tank qualities, and those for steel rails are for heavy sections. The pig-iron prices are for the East Coast hematite and Cleveland iron, both of No. 1 quality and for home consumption. The price of tin-plates is per box of I.C. cokes f.o.b. at Welsh ports, but in all other cases the prices are per ton. Each vertical line in the diagram represents a market-day, and the horizontal lines represent 1*l.* each, except in the case of the diagram relating to tin-plates, where they represent 1*s.* each.

THE BARTLETT SCHOOL OF ARCHITECTURE, UNIVERSITY OF LONDON.—A course of ten lectures on "The Historical Development of Building Construction" is to be delivered by Mr. Martin Briggs, on Wednesdays, at 6.15 p.m., beginning January 25. The fee for the course to students is 10*s.* 6*d.*, to others 1*l.* 1*s.* Application should be addressed to Mr. Walter W. Seton, Secretary, University College, Gower-street, W.C. 1.

TRADING WITH RUSSIA VIA GERMANY.—It has been brought to the notice of the Federation of British Industries that manufacturers in this country are being widely circularised by certain persons in Germany, representing themselves as connected with important interests in that country for the purpose of trading with Russia. The federation accordingly instituted inquiries in Cologne, whence these communications emanated, with a view to discovering the standing of the senders. It has now been ascertained that they are practically unknown in commercial and financial circles, and would appear to have no justification for their statements, nor the means of fulfilling the offers which they make.

WEST OF SCOTLAND ELECTRICITY DISTRICT.—The Electricity Commissioners have provisionally determined the above electricity district, and a local inquiry will be held in due course, of which the date will be announced later. The district embraces the City of Glasgow, the County of Renfrew and parts of the Counties of Ayr, Dumbarton, Lanark and Stirling. Any objections or representations in connection with the proposed area must be made to the Electricity Commissioners at Gwydyr House, Whitehall, not later than December 30 next. Schemes for the constitution of a Joint Authority should also be submitted by the same date. Copies of a map of the proposed area are available for public inspection at the City Chambers, Gasgow, and in the Burgh Chambers of the other important towns concerned in the several counties named above.

## THE REPORT OF THE FRIED. KRUPP COMPANY, ESSEN.

THE report for the financial year 1920–21 states that the iron works, owing to inadequate coal supply, were not fully employed. On account of the reduced coal supply the company was obliged to fall back upon lignite for fuel. The steel works and structural shops were well employed, but the modern open-hearth plant was said to be idle owing to lack of fuel. The Annen steel works showed a deficit. The locomotive and wagon works had disposed of most of their production to the central Railway Department. Under the auspices of the Krupp Company, two contracts for a number of locomotives were entered into with Russia by the German locomotive manufacturers, and the Krupp portion was still in process of delivery. The Germania yard, Kiel, had constructed a new berth for river boats, on which had been laid the keels of a large number of canal boats and steamers.

The balance sheet showed that the "value-regulating fund," for which 75,000,000 marks were reserved in the previous year, had been raised to 150,000,000 marks, leaving aggregate receipts amounting to 268,000,000 marks, against 174,000,000 marks for the preceding year. Expenses in taxes, compulsory insurance and welfare purposes rose considerably above last year's figure, and altogether the company during the financial year under review paid 145,000,000 marks in taxes. The surplus amounted to 98,000,000 marks, against 80,000,000 marks for the previous year, out of which a dividend of 4 per cent. was paid on the 25,000,000 marks of shares of the "A" group and 6 per cent. on the 225,000,000 marks of the "B" and "C" groups. During the three preceding years since 1916–17 no dividend had been paid. A sum of 30,000,000 marks (40,000,000 marks in the preceding year) was set aside for workmen's dwellings, &c., 8,000,000 marks were absorbed by percentage of profit to the Board, 44,400,000 marks were applied to redemption of 40,000,000 shares of the "C" group, and 8,700,000 marks were carried forward.

The "A" "B" and "C" shares arrangement dates from last year, when the "A" shares obtained extra voting powers, but they were to have 2 per cent. less dividend than group "B" and "C." The "B" shares are ordinary shares, whilst the "C" shares, of which a substantial portion passed into the possession of a Dutch syndicate in order to raise sufficient cash "for an emergency," can at any time be withdrawn at an exchange of 110 per cent. This has now been done for the greater portion of the shares of the Dutch syndicate, this business being more in the nature of a temporary advance arrangement than a permanent investment.

Stocks figure in the balance sheet for 807,000,000 marks and credits at banks for 203,000,000 marks, the increase from 75,000,000 marks in the previous balance sheet being owing to a portion of borrowed money still lying at the banks. The loans, 314,000,000 marks as against 40,000,000 marks a year ago, as well as various mortgages, were principally raised for investment in mining property and land. The holdings of shares in other concerns rose from 38,000,000 marks to 321,000,000 marks. New investments have for instance been made in the Konstantin der Grosse and the Helene and Amalie coal-mining concerns. Creditors, &c., increased from 410,000,000 marks to 1,673,000,000 marks, whilst stores and debtors increased from 132,000,000 marks to 1,966,000,000 marks.

An increase of the share capital up to 500,000,000 marks was decided upon. There is to be a new class of preference shares to be offered, against cash payment, to the company's employees at the price of 110 per cent. These new shares ("D" shares) are entitled to a minimum preference dividend of 6 per cent., the maximum dividend being limited to 10 per cent. The shares will be available to all employees who have been at least five years with the company. The shares are to be controlled by a Trustee Association, to be called "Kruppsche Treuhand." When owners of these "D" shares leave the firm, their shares are taken over by the firm at cost price.

PERSONAL.—Messrs. Hollings and Guest, Limited, of Birmingham, announce that they have appointed Mr. D. Landale Freury, of 45, Hope-street, Glasgow, as their sole agent for Scotland.—Mr. William Wright states that he has resigned his position as director of Smeeton-Wright Furnaces, Limited, 56, Victoria-street, London, S.W. 1, and now represents the International Construction Company, Limited (successors to Julian Kennedy, Sahlin and Co., Limited), 56, Kingsway, W.C. 2, as engineer salesman for Great Britain.—Mr. W. E. Warrilow, A.M.I.E.E., who has been identified with trade journalism since 1903, and has held the post of advertising manager to *The Electrician* for the past fifteen years, severed his connection with that journal on December 31 last, with a view to establishing an agency business on his own account.

# THE JOHNSON-BOVING VALVE.

CONSTRUCTED BY MESSRS. GLENFIELD AND KENNEDY, LIMITED, ENGINEERS, KILMARNOCK.

Fig. 1. OPEN.

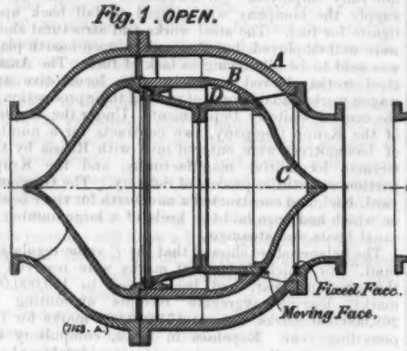



Fig. 2. CLOSED.

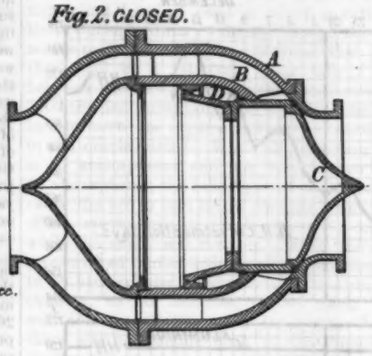



Fig. 3.

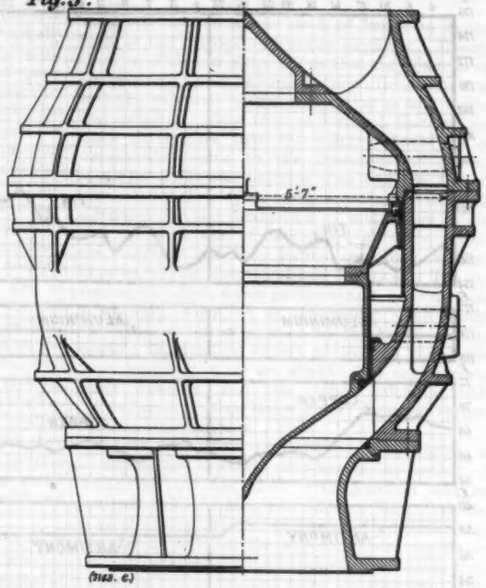
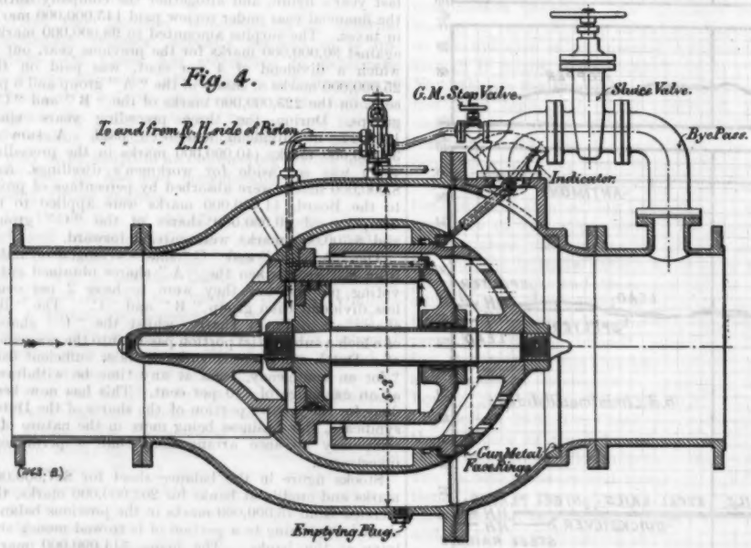



Fig. 4.




THE requirements of large hydro-electric plants have led to a great deal of attention being paid to the main control valves with a view to developing a type of valve which is both easy to control and certain in action, and which offers comparatively small obstruction to flow. Probably the most successful development of this kind, if one may judge from its adoption on a wide range of undertakings, embracing some of the largest being installed at the present time, is the Johnson-Boving valve, for which, with the exception of the United States of America, and Norway, the manufacturing rights of the world are in the hands of Messrs. Glenfield and Kennedy, Limited, of Kilmarnock, whose London Offices are at 39, Victoria-street, Westminster, S.W. 1.

This valve is illustrated in Figs. 1 to 4 herewith, the first two being diagrammatic, to show the action rather than the details of design. In general lines, however, the form shown in Figs. 1 and 2 approaches very closely to that of the larger size Johnson valves, whereas the design illustrated in Fig. 3, is as a rule confined to the smaller sizes. The valve is inserted, of course, in the main, and is operated by the pressure in the main itself, due to the head under which the plant operates. The body of the valve is cylindrical, and, together with its casing, is finished to stream-line form so as to offer as small an obstruction and cause as little loss of energy in the formation of disturbances and eddies as possible. Briefly the valve consists of a cylinder which when the valve is closed rests against a seating in the main, and, when the valve is open, is telescoped back into a casing so as to leave a large free waterway. The valve in its two positions is shown in Figs. 1 and 2, the former showing it open and the latter closed. In these figures the valve proper is denoted by C, the casing into which it is telescoped by B, and the outer casing by A. The casing B is held in position within the outer casing A by means of ribs or webs. The valve C is guided in its movement in two places. The front part of the valve body moves out through a circular stuffing box in the casing B, while at the back of the valve is a ring, fitted with packing, which moves along a parallel length inside the enlarged part of the casing B. The various sections of which the valve and casing are composed, are rendered necessary by manufacturing requirements, as will be at once clear from a consideration of the several diameters, &c. The valve is worked by putting either the space inside the valve and casing, C and B, in connection with pressure from the main supply, and the annular space D in connection with the atmosphere, or *vice versa*. When the valve interior is under pressure, and D is open to the atmosphere, the valve will close; when D is under pressure and the interior of the valve is open to the atmosphere the valve will open.

With correct proportioning no other working parts are necessary with the larger valves for low heads as may be seen from Fig. 3 which shows a 48-in. valve having a maximum internal diameter of 67 in. In this figure the parts referred to will be easily recognised as they are much of the form shown in the more diagrammatic drawings of Figs. 1 and 2. Attention may be drawn to the packings, and to the fact that the parallel lengths of both the valve and inner casing or shell are lined with gun-metal. The water under pressure for operating the valve is conveyed through the dotted passages in two of the ribs connecting the inner and outer casings. The valve seating is of gun-metal, and the valve face is fitted with a corresponding ring of similar material. With smaller valves for high heads the construction is modified and the valve, instead of being dependent on differential action, is positively operated by a piston housed inside the valve body, and is guided by the casing stuffing-box, and the piston and tail rod. These points will be at once clear from Fig. 3. Little additional description is necessary of this figure; the main points and action of the valve will be readily appreciated.

The Johnson-Boving valve is operated by a four-way valve (above in Fig. 4), having connections to and from both sides of the piston, from the pressure supply, and to an exhaust. The construction of the fourway valve is such that when one side of the piston is put in communication with the pressure supply, the other side is open to the exhaust, and *vice versa*. Attached to the valve in Fig. 4 will be seen a small telescopic connecting rod. This is part of an indicating device to show whether the valve is functioning correctly. The valve face is fitted with a gun-metal ring, and the valve seating in the casing is also formed of a gun-metal ring. Hydraulic leathers are used to pack the stuffing boxes, &c. Fig. 4 shows a by-pass which it is usual to fit so that the pressure on the main valve may be relieved before opening.

All circular joints between the several castings are recessed flanged joints, gutta-percha cord being laid in the recess and prevented from blowing out by the spigot on the male end. The valves can be arranged to work in either the horizontal or vertical position. When used in the former a drain plug is provided at the lowest part of the enlarged section of the casing, in order to clear the casting of water, to prevent damage by frost, &c. The simplicity of the design, and the protection afforded to all working parts when in the open position enables this valve to be kept open for long periods without risk of failing to close promptly when required. The annular area surrounding the inside casing is ample, and the shape of this casing such that the least possible interference with the flow is presented to the stream of water.

In order to obviate all risk of water hammer it is recommended that the valve should not be closed or opened in less than 1¼ minutes to 2 minutes, though this time is somewhat dependent upon the conditions of the installation. By means of solenoid control these valves may be worked from a distance so that they may be located where desirable in the pipe line, and yet be controlled from the power-house.

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THE LATE MR. ROBERT T. NAPIER.—We regret to have to announce the death, which occurred suddenly at Glenallan, Dunblane, on December 27, of Mr. Robert Twentyman Napier. Mr. Napier was 71 years of age; he was the eldest son of Mr. James R. Napier, F.R.S., and the grandson of the late Mr. Robert Napier, of Shandon. He received his education at Glasgow High School and at Glasgow University where he studied under Professor Rankine. He then served an apprenticeship with Messrs. Robert Napier and Sons, Lancefield. Following this, Mr. Napier entered the service of Messrs. Denny, of Dumbarton, and later that of Messrs. John Penn and Sons, Greenwich. In 1878, in partnership with his brother, Mr. Henry M. Napier, with Mr. Alexander Shanks and Mr. David Bell, he started shipbuilding at Yoker, under the name Napier, Shanks and Bell. He retired from the firm twenty years later owing to failing health. He became a member of the Institution of Civil Engineers in the year 1898.

## RAILWAY ELECTRIFICATION.*

By SIR VINCENT L. RAVEN, K.B.E., M.Inst.C.E., M.I.Mech.E.

THE steam locomotive, which we have associated for so many years with the working of our railway traffic, is a machine with which we all find it difficult to part; the inclination being to resent any proposal to supplant its use for a more modern form of locomotion. Outside sentiment, however, the principal reason for adhering to the steam locomotive is the comparatively great cost in changing from one system to another; but before this can be put down as unsurmountable, it is right that all the reasons for a change should be considered, and the savings and advantages put forward clearly so as they may be set against the expense which is involved when any great alteration of principle is undertaken.

The railways of this country are now formed into groups, and it is hoped by those who put forward these amalgamations that great economies would be brought about. Economies must be made if dividends are to be paid on the capital invested; if a fair return is not forthcoming, then investments cease, and paralysis of the enterprise takes place which would be a most serious condition, as railways affect very largely all industries of the country. It is necessary therefore that we should consider every means by which the working can be so changed as to bring about general advantages which lead to economy. The North-Eastern Railway Company is by no means without knowledge and experience of electric traction, as the passenger service around some of the busiest suburban districts of Newcastle has for the past seventeen years been worked electrically; they have also equipped a mineral line from Shildon to Newport with electric locomotives, which have absolutely replaced the steam locomotives for this particular service; therefore they can claim first hand data for reasons arrived at.

This paper deals in a general way with some of the advantages which may result from the substitution of electric for steam locomotive operation, but must not be taken as applying to any particular line whereon some of the advantages might or might not be obtainable. Taken as a whole, it will be shown that the advantages can all show a definite financial economy in operating expenses. In considering the substitution of electric for steam locomotives it will be evident that there are a number of prominent features in both types which are perhaps best expressed by the terms "for and against"; or "advantages" and "disadvantages." Admittedly, the practical experience of locomotive engineers in this country has been almost exclusively confined to the steam locomotive, and for that reason it would probably be well to enumerate in the first instance the mechanical limitations and disadvantages which, every engineer will agree, exist in the steam locomotive.

The mechanical disadvantages of the steam locomotive may be briefly summarised as follows: The locomotive being a complete independent unit, its power cannot be greater than the capacity of the boiler. To increase the boiler capacity obviously implies increased dimensions and weight, both of which offer grave difficulties in regard to clearances and strengthening of bridge structures. It is known that on many railways in Britain the limit of weight has been reached, and further development of power is only possible at enormous expense. The boiler, cylinders, valve gear, crankshafts and all reciprocating parts are costly to maintain. Turntables, fuelling plant and water supply appliances must be provided. The cab is small and open to the weather, involving discomfort to the locomotive crew. The locomotive radiates heat and uses coal all the time steam is up, that is, during many hours when it is doing no work, and either standing by or coasting. The wear and tear of the locomotive on the track is considerably increased by the impossibility of accurately balancing the reciprocating parts.

The case for the electric locomotive may be set out by the brief statement that it is not hampered by any of the above-mentioned objections. In addition, one might point out that it possesses other important qualifications such as: Simplicity of mechanical construction and operation. Increased power of acceleration. Higher scheduled speed due to the possibility of heavy short-period overloads resulting in more frequent service and increased use of existing tracks. Uniform turning effort resulting in better factor of adhesion at starting and on gradients. Absence of all reciprocating movement and accurate balance of all rotating parts. Facilities for driving from either end of a locomotive. Accessibility of mechanical and electrical parts. Better accommodation for locomotive crew by reasons of increased cab area, and by closing in and heating the cab. Possibility of coupling two or more locomotives together under the control of a single driver.

One essential difference in operation between an electric and steam locomotive, where the former can show a very definite advantage, lies in the preparation and setting by of the locomotive. An electric locomotive is always available for service at a moment's notice since the electric motors only require that they should be kept clean, lubricated and provided with brushes in order that they may be always ready for immediate use by simply connecting them to the distribution line. In order to start up an electric locomotive which is standing the driver only has to step on board, close certain switches and move the controller handle. When the day's work is over, nothing has to be done except ordinary examination, oiling and cleaning for the next trip.

On the other hand, the process of preparing a steam engine for duty involves considerable time and labour. About 3 hours before the driver and fireman come on duty, the steam raiser has to make up and light the fire and attend to it until the driver takes charge, after which it takes the driver and fireman about 60 minutes to complete the preparation of the engine for its day's work. While the engine is at work, water and coal have to be taken, and very often the fire has to be cleaned and made up. After the day's work is finished, the fire has to be thrown out and fire-bars cleaned, smoke-box ashes to be thrown out of the smoke-box, and the tubes have to be cleaned by compressed air. The top of the brick arch has to be cleaned down and the brick arch itself has to be renewed frequently. About every sixth trip, the boiler washer has to clean the boiler to keep it fit for producing steam. The boilersmith has to examine and renew the lead plugs, and attend to leaky tubes and many of the other small repairs to the boiler in order to enable the engine to run its stipulated mileage. The shed fitters have a large number of working parts to keep in order which have no corresponding part on an electric locomotive.

Then again, when the electric locomotive has been put into service it can remain at work continuously for at least 20 hours in every 24, as the lubrication and the small amount of cleaning that is necessary for the electrical equipment can be given by the crew at wayside stops, during running and between trips. It may be contended that the driver will be fully occupied during running in watching signals and controlling speed, and will not be able to attend to these small items; but it must be remembered that, although a second man is not required in the operation of an electric locomotive, it has so far not been usual to allow one-man operation. This means that the second man in the cab will have plenty of opportunity to attend to cleaning and inspection of all parts where this can be done without interfering with the running.

Therefore, an electric locomotive need only go into the sheds in the ordinary way for cleaning and inspection of brake blocks and certain of the less accessible parts between the frame. On the steam engine, however, the boiler, fire and smoke-box, in addition to the much larger number of mechanical parts such as cylinders, valves, link motions, &c., are responsible for a considerable amount of time taken up in examination, and attention which might otherwise be utilised for hauling traffic. Due to these two differences in operation, therefore, namely, preparation for service and ordinary service attention, the electric locomotive can be longer in revenue earning service than the steam locomotive; thus, provided traffic conditions will permit, the electric on these two counts alone is capable of dealing with a considerably larger ton mileage than the steam locomotive.

Here it should be said at once that although the electric locomotive may be capable of remaining in service for a longer period of the day than the steam locomotive, it is not possible to obtain the full advantage due to this feature without adopting some system of "pooling." It is evident that the crew of the electric locomotive, even though their duties are very much lighter than those of the crew of a steam engine, cannot remain at work for a longer period owing to present-day regulations. This might be held to neutralise to a large extent the particular advantage of the electric locomotive, but it would seem on examination that the objections which are made to "pooling" of steam engines do not hold good in the case of electric locomotives. The number of adjustments that are required in the case of a steam engine and the fact that a reasonable period must be allowed for making these adjustments between trips, added to the difference in the running made by the care or carelessness of the driver, and the natural disinclination of one man to do those things which another has left undone, add considerably to the difficulties of "pooling" of steam engines. On the other hand, due to the simplicity of control, in the case of the electric locomotive, there is no objection to "pooling" and so full advantage can be taken of their capacity for working longer hours.

In addition to this, since the only requirements of the electric locomotives in the ordinary condition of service consist of cleaning and adjustments carried out in the ordinary routine inspection, it is possible when some occasional derangement of schedule occurs, to keep these engines in continuous service for two or three days, by omitting the cleaning and routine inspection for that period. It should, of course, be understood that the engine is in good repair; but provided this is the case, there is nothing to prevent continuous service. Such an extension of time in service would not be practicable with steam working. This advantage applies particularly to the case of the electric shunting locomotives, which are frequently kept in service for six days continuously.

The following examples may be quoted to illustrate the possibility of utilising this advantage of the electric locomotive:—

(*a*) On the Chicago, Milwaukee and St. Paul Line, passenger locomotives run through from Harlowton to Avery, a distance of 440 miles. When the gap between Avery and Otheilo is electrified the same engine will run through from Harlowton to the Pacific Coast, a distance of about 850 miles.

(*b*) On the Norfolk and Western Railroad in the last six months of 1918, the average mileage worked by each of 12 electric locomotives was 22,250, some 3,700 miles per month compared with steam engines on the same line which worked some 1,500 miles to 1,600 miles per month. The average engine hours worked per day were 18 to 20 in the last six months of 1919.

(*c*) On the New York, New Haven and Hartford Railroad the average mileage worked per day by electric locomotives is shown on the following table. These figures are very high as compared with steam practice.

NEW YORK, NEW HAVEN AND HARTFORD RAILWAY.

*Average Mileage Worked per Day by New York, New Haven and Hartford Railway Electric Locomotives Compared with North-Eastern Railway Steam Locomotives.*

| | All Locomotives. | | |
|---|---|---|---|
| | September 1915. | April, 1919. | N.E.R. 1919. |
| Passenger | 183·63 | 210·30 | 51·58 |
| Freight | 105·68 | 81·61 | 40·11 |
| Shunting | 113·01 | 98·84 | 90·53 |
| | Serviceable Locomotives. | | |
| Passenger | 214·98 | 229·40 | 91·84 |
| Freight | 122·96 | 103·50 | 61·50 |
| Shunting | 129·15 | 112·96 | 101·27 |

(*d*) On the North-Eastern Railway, the result of the Newport and Shildon working between 1914 and 1920 is in accordance with the following statement:—

*Newport and Shildon Electrification.*

| | Train Miles per Train-Hour. | | Wagon Miles per Train-Mile. | | Wagon Miles per Train-Engine Hour. | |
|---|---|---|---|---|---|---|
| | 1914. Steam. | 1920. Electric. | 1914. Steam. | 1920. Electric. | 1914. Steam. | 1920. Electric. |
| January | 6·3 | 7·9 | 45 | 54 | 203 | 358 |
| February | 6·3 | 8·6 | 44 | 55 | 204 | 390 |
| March | 6·6 | 8·6 | 43 | 54 | 206 | 386 |
| April | 6·4 | 9·0 | 43 | 53 | 202 | 390 |
| May | 6·5 | 9·3 | 44 | 51 | 206 | 385 |
| June | 6·7 | 8·8 | 43 | 53 | 211 | 377 |
| July | 6·4 | 9·3 | 45 | 52 | 214 | 390 |
| August | 6·6 | 8·5 | 43 | 53 | 210 | 367 |
| September | 6·5 | 8·8 | 45 | 52 | 212 | 387 |

I have also taken out some figures for this branch showing the mileage run by the electric engines to-day which is 116 train miles per day per engine in traffic, as compared with 55 for the steam engines in 1914.

The fundamental difference between an electric locomotive and a steam engine lies in the fact that while the latter generates its own power, the former is only a transformer of the power, which is generated at the power station or stations, into haulage power on the track. One consequence of this difference is that the working of a steam engine depends to a large extent on the skill of the crew in attending to the fire and the water level, and in looking after a large number of mechanical parts, and generally nursing the engine so as to get the best out of it. The working and condition of an electric locomotive is not nearly so dependent upon the skill of the driver and his assistant. Full power is always available and the power and speed which can be developed at any moment are only limited by the initial design of the electrical equipment and by the mechanical construction.

The driver of an electric locomotive need never hesitate to exert the full power for the sake of nursing the locomotive, and all trains within the limit of load for which the locomotive is designed can be hauled up the maximum gradient at full speed. It is evident, too, that the overload capacity of the generating station or stations will be very much greater than that of a single boiler mounted on a steam locomotive; and since the capacity of an electric motor is in practice only limited by heating effect, it follows that an electric locomotive is capable of a very large overload for a short period. That is to say, that provided the average work performed does not exceed that for which the locomotive was designed, the work done may, for short periods, be greatly in excess of the average. The result of this is that the speed, when climbing a gradient, can be much greater with an electric locomotive than with a steam locomotive of the same nominal horse-power, because the extra work done by the former is compensated for by the light duty during periods of running on the level and on falling gradients when the motors have time to cool down.

The limitation of boiler capacity in the case of a steam engine combined with the different characteristics of steam and electric locomotives gives the latter an additional advantage in the question of speed on gradients. As the governing factor in the power of a steam engine is the capacity of the boiler, which is practically a fixed quantity, the horse-power output of the locomotive is approximately constant over a wide range of speed. In other words the maximum pull of an electric locomotive can be maintained until a certain definite prearranged speed is attained; whereas a steam locomotive can only exert its maximum pull at the moment of starting, after which the pull is reduced as the speed increases. In the case of our 0-8-0 mineral engines the reduction in the maximum pull is about ¼ ton for each mile per hour that the speed is increased. So that if the maximum pull at the moment of starting is 13 tons, the maximum pull when the engine is going at 12 m.p.h. will be 10 tons. Thus the speed of the train falls to a marked extent whenever the train has to climb a gradient. This reduction of speed on a gradient is not nearly so marked in the case of the electric locomotive, for there being no similar limitation to the amount of power available, the relation between speed and tractive effort is quite different, and the demand for greater tractive effort is supplied by a higher output from the power supply system. Thus, when determining the initial characteristics of an electric locomotive for a given service, the

* Paper read before the North-East Coast Institution of Engineers and Shipbuilders, on December 16, 1921 (*slightly abridged*).

speed up the ruling gradient can be fixed at any desired value; and since the efficiency is practically constant over a wide range of load, the speed on the level can be maintained at the same value, if desired, without loss of efficiency. In comparison with the steam engine working, where the speed is greatly reduced on a gradient, this enables a much higher average speed to be maintained over the whole line; which is equivalent to saying that with electric working the general average speed can be considerably increased without any increase in the maximum speed.

If other factors, such as draw gear and braking facilities, permit, this characteristic of electric locomotive operation would allow goods trains to travel at an average speed more nearly approaching that of passenger traffic. The result of this would be a more regular flow of traffic over the line, and the necessity for side tracking the goods trains to allow passenger trains to pass would be reduced. In certain cases, owing to this characteristic alone, where a line is being worked at its maximum capacity under steam operation, and is yet unable to deal with the required traffic, a substitution of electric for steam engine working would avoid the necessity for incurring large capital outlay in doubling or quadrupling the track and providing additional passing places, &c. A further advantage which can be obtained owing to this increased average speed of travel is better traffic working. In dealing with the traffic carried a greater number of trains can be run, and these trains complete their journeys in less time than with steam working, thus enabling better use to be made of the available rolling-stock. This is particularly true in the case of goods wagons.

As an example of the savings which may be effected in certain cases directly due to the advantage of electric locomotive operation as just stated, the following data may be given. These data refer to a length of single track on an existing steam railway. The data have been worked out as it has now been decided to make a start with the electrification of this section. It should be stated that the case cited is one particularly favourable to electrification. The length of the line is some 250 miles, mainly single track, and containing in many places exceptionally steep gradients, reverse gradients and sharp curves. The total goods traffic under the conditions obtaining in 1918 was some 13,000 tons per day despached in the direction of falling grades, but the traffic is rapidly increasing and the estimates are worked out for an assumed traffic 50 per cent. in excess of this. In order to carry this traffic it was estimated by the railway company that they would have to make deviations, &c., which practically amounted to providing double track for some 200 miles and building a new line over lighter grades in parts.

Electrification will obviate the greater part of this expenditure. The line as worked under steam conditions is divided up into six sections, and the train load differs for each section. With electric operation this frequent breaking up of trains would be unnecessary, and the full weight trains would be hauled right through, without alteration. This reorganisation was calculated to effect a reduction in the annual train mileage of through goods trains of about 25 per cent. for the same total ton mileage. At the same time the average speed of travel would be increased, the total time for the double journey being reduced from about 56 hours to 26 hours. The saving in new wagons due to this acceleration of service was estimated to amount to approximately four hundred and twenty-three 40-ton wagons, or the equivalent.

Partly as a result of the increased average speed and partly as a result of the longer time that electric locomotives can be kept in service as compared with steam engines, a considerable saving can be effected by electrification in the total number of engines that are required to deal with any given volume of traffic. As an example of the saving of locomotives, the following table may be given showing what has been done on the Chicago, Milwaukee and St. Paul Railway:—

CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY.

*Steam Locomotives replaced by Electric Locomotives (Missoula and Rocky Mountain Divisions).*

| —— | Number. | | Average Weight. | | Total Weight. | |
|---|---|---|---|---|---|---|
| | Steam. | Electric. | Steam. | Electric. | Steam. | Electric. |
| | | | tons | tons | tons | tons |
| Passenger .. | 19 | 12 | 164 | 269 | 3,120 | 3,230 |
| Freight .. | 85 | 30 | 188 | 257 | 16,000 | 7,720 |
| Shunting .. | 8 | 3 | 106 | 63 | 848 | 190 |
| Total .. | 112 | 45 | — | — | 19,968 | 11,140 |

Mr. Beeukes, the electrical engineer to the railway, has estimated from actual records that electrification has enabled about 30 per cent. more tonnage to be dealt with in about 80 per cent. of the time formerly required under steam operation, which means an effective increase in the capacity of the line due to electrification of 32·5 per cent. These figures give some idea as to the effective increase in the capacity of the line due to electrification.

Due to its uniform turning efforts, the electric locomotive has a further advantage when starting trains. In the case of the electric engine the increase of the effort at starting above the normal effort is greater than in the case of the steam engine, and can be kept up for a longer time. For example, take the case of the passenger locomotive whose average or continuous rating is 1,400 b.h.p. If such an electric engine started with a pull of 7 tons, it could maintain this pull up to a speed of 45 m.p.h. At this point the brake horse-power exerted is about 1,900. If necessary, when accelerating up a steep grade, this locomotive can produce as much as 3,000 b.h.p. The advantage of this is chiefly apparent in the case of stopping passenger trains, when, by increasing the acceleration the average speed can be considerably raised, and goods trains when starting from intermediate stations, and especially when coming out of refuge sidings after a passenger train has passed. If an electric engine stands for an hour on an up grade there is no reduction in its maximum pull. When a steam engine stands for some time the cylinders are cooled, and the engine cannot exert its maximum pull until they are heated to about the temperature of the entering steam. It has been observed that this reduction of pull due to cooled cylinders is as much as 25 per cent.

As there is no necessity for taking in water for electric locomotives—with the exception of the small quantity that may be required to steam heat existing passenger stock in certain cases, it is unnecessary to provide either water columns or troughs on lines designed for electric operation. Similarly, there is no need to provide coaling stations, coaling plant or ash pits for electric operations. Again, electric locomotives are designed for double end driving, and there is no need for turntables or the delays in turning engines; thus, in these items, time can again be saved and added to the useful working time that the engine is in service. Further, because the electric locomotive requires no attention whatever while lying by, a saving can be effected in the crew's time, since it is unnecessary for an electric locomotive to be in charge of the crew while it is lying over. It can be locked and left in a safe place. In the case of a steam engine the time occupied in ineffective locomotive duties is over 25 per cent. of the total enginemen's time as shown by the Ministry of Transport's figures for North-Eastern engines. While it is obviously impossible owing to traffic arrangements, &c., to save the whole of this idle time, there is no doubt that a considerable portion of it may be saved by electric operation in conjunction with the "pooling" system to which I have previously referred.

CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY.

*Comparison between Coal Used for Steam Working and Energy Purchased for Electric Working.*

| —— | October. | | November. | | December. | | Average. | |
|---|---|---|---|---|---|---|---|---|
| | 1915. Steam. | 1916. Electric. | 1915. Steam. | 1916. Electric. | 1915. Steam. | 1916. Electric. | 1915. Steam. | 1916. Electric. |
| *Passenger traffic—* | | | | | | | | |
| Units purchased per train-mile.. | — | 30·3 | — | 27·4 | — | 29·9 | — | 29·1 |
| Pounds of coal used per train-mile .. .. .. .. | 171 | — | 201 | — | 193 | — | 188 | — |
| Ratio, pounds of coal per unit .. | 5·63 | | 7·34 | | 6·46 | | 6·46 | |
| *Freight traffic—* | | | | | | | | |
| Units purchased per 1,000 gross ton-miles .. .. | — | 37·4 | — | 39·1 | — | 42·0 | — | 39·4 |
| Pounds of coal used per 1,000 gross ton-miles.. .. .. | 247 | — | 294 | — | 291 | — | 276 | — |
| Ratio of pounds of coal per unit | 6·61 | | 7·52 | | 6·93 | | 7·01 | |

A very serious disadvantage of steam operation is that the steam engine radiates heat and uses coal all the time that steam is up, that is, during many hours when it is doing no work, and either standing by or coasting. On the other hand, the electric locomotive uses no power whatever (except for lighting and heating the cab) unless actually running and doing work. It is quite evident that for this reason electric operation makes possible a very considerable saving in fuel as compared with steam operation. This saving is all the more important in proportion as the duty performed by the engine is the more intermittent, especially since the electric locomotive has a much higher efficiency, when only partly loaded, than the steam engine. This saving in fuel consumption, rendered possible by the adoption of electric working, is becoming increasingly important as the high price of coal suitable for steam locomotive firing is more and more pronounced. It has been shown that a saving is effected due to less consumption of power in idle time, but the main fuel saving which can be introduced by electric operation is due to the very much more efficient combustion of the fuel that can be obtained under the boilers of modern coal-fired power stations than is obtained by burning relatively small quantities of coal on the individual engines. This saving in fuel is one of the greatest advantages to be obtained by electrification, and a number of comparisons have been made in the United States between the coal consumed for a certain service as worked by steam and electric locomotives, notably on the mountain sections of the Chicago, Milwaukee and St. Paul Railway, which have recently been electrified.

The figures given in the table above were compiled for the Rocky Mountain Division for steam operation during October, November and December, 1915, and for electric operation on the same division during the same months in 1916.

From the figures in this table it is clear that one unit of electrical energy delivered by the power company to the railway company's line does the work of between 6 lb. and 7 lb. of coal on steam locomotives. It is well known, with an up-to-date power station, a unit of electricity is produced with less than 2 lb. of coal.

This is the result obtained on a railway which is exceptionally well suited to electrification owing to the nature of the line which passes over two or three ranges of mountains; but although an equally good result is hardly to be expected on a railway such as the North-Eastern where the greater part of the line runs over fairly flat country, the saving in fuel that would be realised on this line would still be very substantial. Careful calculations show that as a result of electrification the weight of the low-grade coal that would have to be burned in the modern electric power station, from which energy would be taken for working the traffic electrically, would not be more than 40 per cent. of the weight of high grade coal used on steam locomotives to do the same work. On this basis, if we take the North-Eastern coal consumption in 1919 (which was 921,480 tons) we find that if electric working were substituted for steam there would be a saving of about 550,000 tons per annum, and a further saving would be effected due to the fact that the low-grade fuel would be substantially cheaper than the high-grade locomotive coal. In addition to this, a large proportion of the stand-by fuel losses inherent in steam engine operation may be eliminated in electric operation. To gain some idea of how great this saving may be, an analysis was made of certain heavy grade runs on the Chicago, Milwaukee and St. Paul Railway made by steam operation, in which it was found that the stand-by fuel losses amounted to 27½ per cent. of the total coal burned.

With electric operation, a much smaller tonnage of coal has to be carried over any line—for the same traffic—and this quantity is carried to fewer unloading points, namely, the power stations. This results in the clearing from the line of a number of local trains. A number of wagons will also be set free which, with steam operation, would have to be employed in carrying coal. In the example quoted previously where the calculated savings were given, resulting from the electrification of a certain section of line, it was estimated that there would be a saving of ninety-three 40-ton wagons due to the reduction in fuel consumption.

On lines where the gradients are long and severe, the equipments of electric locomotives can be arranged for the generation of power, so that when a train is descending a gradient the motors become electric generators and return power to the distribution system, and in so doing produce a retarding force, holding the train on the gradient without the use of the mechanical brake. This gain is most important on the line where the heavily-loaded trains are, in general, running down the grade. The advantages which may be obtained by making use of this regenerative property of electric locomotives consist in:—

(*a*) A saving of power and fuel, because the potential energy of the loaded trains descending the gradient is utilised in the form of electrical energy in driving the returning trains up the grade.

(*b*) An increase in the life of the brake blocks since the brakes need only be applied for bringing the train to a standstill, or for unexpected checks, with a consequent reduction in the wear of the blocks and prevention of trouble due to the expansion of the tyres with heating.

(*c*) A possible saving in damage to couplings due to the much smoother action of regenerative braking.

(*d*) It is possible to take goods trains down long gradients at a higher speed by using regenerative braking than by relying on the ordinary brakes to control the speed. This is possible partly because the retarding effect of the locomotive when working regeneratively increases if the speed increases, whereas the retarding force due to the brake falls off with any rise in speed. Thus regenerative working is a stable condition, while the action of the brakes is unstable, and if the train once exceeds a certain speed the brakes are powerless to get the train under control again. Further, the speed of a train down a long gradient must not be such as to cause overheating of the brake blocks and wheel tyres. With regenerative working the brakes are held in reserve and the speed is only limited to such a value that the brakes can stop the train at any signal if necessary. Again, the regenerative action is continuous and does not tend to fall off after extended use, whereas under certain circumstances the air pressure or the vacuum on which the brakes depend may gradually fall and there may be no opportunity to restore the pressure or the vacuum without letting the train get out of control.

(*To be continued.*)

## STRESS CONCENTRATIONS DUE TO NOTCHES AND LIKE DISCONTINUITIES.*

By Professor E. G. COKER, F.R.S., and Dr. PAUL HEYMANS, University College, London.

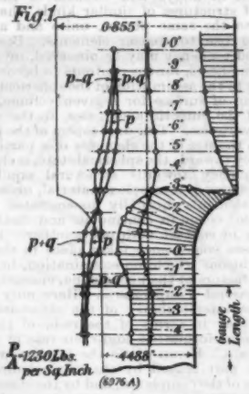
IT is well known that discontinuities in loaded members cause, in general, severe stresses in their neighbourhood, and therefore do not allow full economy of material to be realised in cases where such discontinuities are

* Part of a report on "Complex Stress Distribution" read at the meeting of the British Association at Edinburgh, September, 1921.

inevitable in practical construction. In the majority of such cases, it is difficult, and sometimes impossible, to calculate the maximum stresses produced, and experience in the behaviour of similar members is then usually relied on, in the absence of an accurate knowledge of the stress distribution which exists. The stress distribution caused by discontinuities has also become of importance in recent years in the testing of materials, and a considerable field of inquiry has developed on the behaviour of materials subjected to impulsive loads, which produce stresses at definitely-shaped discontinuities sufficient to cause rupture at the chosen section, and in this way a classification of materials is obtained which has proved of great value in engineering practice, although, with our present knowledge, such testing operations can only be regarded as of an empirical nature.

In the present report a brief account will be attempted of some experimental investigations which have been made on discontinuities by photo-elastic methods

Fig. 1.




described in a previous report,* whereby stress distributions have been determined sufficiently completely to allow of a fairly accurate value being assigned to the maximum stresses experienced under given loads. In all these cases, the member, a flat bar, has been subjected to plane stress, and the results are, therefore, only applicable strictly to this kind of stress, except in some cases which will be noted.

An interesting case of a discontinuity of a simple kind arises where it is necessary to alter the cross-section of a member in a definite manner, as, for example, in a flat tension member or a cylindrical rod. This case occurs in a variety of instances in practice, and the salient fact in connection with this type of discontinuity is the increase of stress which occurs near the join of the smaller to the larger section when the contours are formed by circular arcs, which are tangential to the boundaries of the smaller section and intersect the larger at an angle.

The maximum stresses reached are shown experimentally not to occur exactly at the joins,† but slightly beyond, at places where a tangent to the contour makes a small angle to the axis of the specimen. Thus, for example, in a case where the smaller breadth of a flat bar is 0·4488 in. and the larger 0·855 in., connected by arcs of 0·3 in. radius, the maximum stress is found at a point of the curved contour where a tangent line makes an angle of about 8 deg. to the line of pull, and the stress intensity is nearly 20 per cent. greater than the uniform stress in the smaller section.

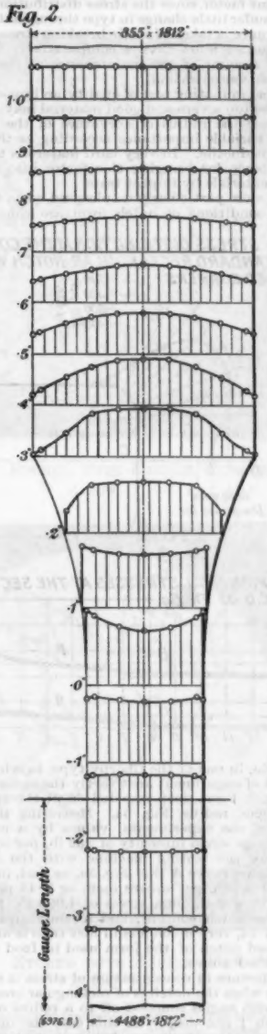
The distribution in this member at the contour is shown in the accompanying Fig. 1, from which it will be observed that a maximum stress of 1,470 lb. per square inch is reached when the uniform stress in the smaller section is 1,230 lb. per square inch. As might be expected, this maximum stress increases with decrease of radius at the re-entrant angle, and in a very nearly similar contour, but with a re-entrant angle of $\frac{1}{16}$ in. radius, an increase of stress of 57·5 per cent. was observed.

The type of contour shown in Fig. 1 is probably more frequently met with in British practice than any other. It is, for example, adopted by the Engineering Standards Committee as a standard form of end (with a radius of 1 in. for the connecting arc) for tension test members of boiler plates and like material.

As will be observed from the contour stresses, the distribution in the region of the discontinuity is extremely variable, and in the interior of the plate is of a complex nature.

Along the central line, for example, there is a gradual change from high to low tensional stress $p$ in the direction of pull, accompanied by a variable cross-stress $q$, which latter has a maximum tensional value very near to the section where the width of the member begins to increase, but it soon changes sign and becomes a small cross-compression stress, and ultimately vanishes when the stress in the larger section becomes a uniform tension. A map of the stress in the direction of the line of pull, for this case, is drawn to a distorted scale both horizontally and vertically Fig. 2, in order to show the distributions at sections $\frac{1}{10}$ in. apart, and from this it will be observed that the greatest variations of stress occur at the contours, and, in general, within the region of complex

Fig. 2.




stress, the maximum stresses occur at the sides in the smaller section and along the axial line in the larger section. The type of stress distribution shown here does not, however, appear to persist beyond the elastic limit in ductile material, and the variations of stress shown in the figure probably tend to equalise, and hence fracture does not necessarily begin to take place at the point on the contour where the maximum stress is indicated. In brittle materials, however, where little change occurs in the type of stress distribution, it is found that fracture occurs very frequently at this cross-section. This latter result, which is often ascribed, and generally erroneously so, to imperfect centreing of the specimen in the testing machine, is therefore more probably explained by the facts of the distribution observed.

Another fact which emerges from the experimental observations is the penetration of complex stress into the parallel part of the reduced section, and it is easy to show for this case, where the model is one of three-tenths scale of an Engineering Standards Committee test bar, that complex stress occurs for a distance of 0·185 in. within the parallel part, so that in a specimen of this size and contour, and a parallel part 0·37 in. long, there is no pure tension stress at any cross-section between the enlarged ends, except possibly the central one. In a geometrically similar test bar, with connecting arcs of 1 in. radius, it would appear, therefore, that a total length of 1·23 in. of the parallel part is in a state of complex stress, and since it is found experimentally that complex stress distribution at the ends does not vary to an appreciable extent as the length of the parallel part increases beyond this, it may be inferred that, within the elastic limit, a sufficiently short tension test member under load may be in a state of complex stress, which has little or no resemblance to pure tensional stress at any part of it, and it is therefore likely to give fallacious results for practical applications.

In the example cited above, the limiting length of the parallel part for which there is no pure tension stress across the sections between the shoulders, is 1·23 in., and, for such a case, complex stress occurs at all sections, except possibly the central one.

The danger of accepting tension tests on short specimens as representing the true behaviour of the material in pure tension is clear, especially as it is not difficult to show* that in turned specimens of the same contour as a flat-bar specimen, the complex stress in the former extends further into the gauge length than in the latter.

In another standard form, widely used in Continental practice, the enlarged ends are gradually tapered towards the gauge length and have straight-line contours, which join the parallel part at a very obtuse angle. At this junction photo-elastic observations show that there is a small amount of stress concentration, probably not more than 10 per cent. greater than the stress intensity in the gauge length and, moreover, very localised in extent.

In still another form, used by Professor Dalby, mainly to avoid contact stresses and local indentations due to extensometer screws, the extremities of the gauge length are defined by two thin collars turned on the specimen with connecting arcs to the main body of 0·04 in. radius. In this case the stress concentration is very local and is rather more than 30 per cent.† of the mean average stress, and is symmetrically disposed with

Fig. 3a. STRESS DISTRIBUTION AT THE CONTOUR OF A VEE SHAPED NOTCH.

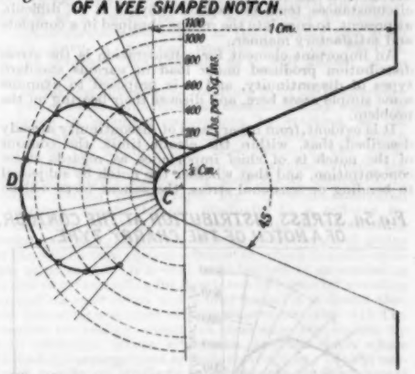



Fig. 3b PRINCIPAL STRESSES AT THE SECTION C.D. OF FIG. 3a.

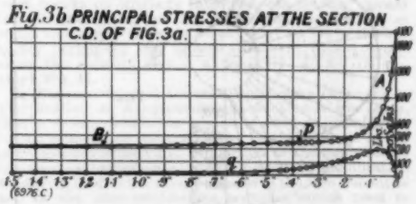
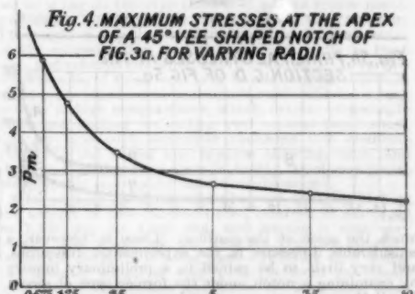



Fig. 4. MAXIMUM STRESSES AT THE APEX OF A 45° VEE SHAPED NOTCH OF FIG. 3a. FOR VARYING RADII.




reference to the collar. It is, moreover, practically independent of the radius of the fillet within wide limits, and, in that respect, differs from the stress at a re-entrant angle, where the radius of the fillet is the main factor which determines the stress concentration.

Observations of stress distribution by photo-elastic means indicate, in general, that the stress concentrations described above tend to equalise more or less in the plastic stage. Thus in a nitro-cellulose model, of the form used by the Engineering Standards Committee, it is observed that the varied colour effects, which mark the penetration of complex stress within the gauge length, tend to recede towards the enlarged ends as the material passes into the plastic state, and, in general, at fracture the line of greatest colour variation is concentrated near to the section where the curved contours meet the parallel part of the gauge length, so that it seems possible in ductile material that nearly the whole of the parallel part of the gauge length ultimately comes into a state of uniform stress.

*Discontinuities in Materials subjected to Impact Tests.*—The practical necessity of ascertaining the ability of materials to withstand suddenly applied loads has led to the introduction of shock tests of various kinds, and these are generally arranged in such a manner that

* "Stress Distributions in Engineering Materials," B.A. Report, 1914.

† "Photo-Elastic Measurements of the Stress Distribution in Tension Members used in the Testing of Materials," by Professor E. G. Coker, F.R.S., Min. Proc. Inst.C.E., vol. ccviii, 1918–19, Part II.

* "Photo-Elastic Measurements of the Stress Distribution in Tension Members used in the Testing of Materials," by Professor E. G. Coker, F.R.S., Min. Proc. Inst.C.E., vol. ccviii, 1918–19, Part II.

† "Contact Pressures and Stresses," Professor E. G. Coker, K. C. Chakko and M. S. Ahmed, Proc. Inst. Mech. Engrs., March, 1921.

fracture of the specimen shall occur, generally, with a single application of a load applied by a falling weight or swinging pendulum. Such tests are essentially different from static tests of material, and, in general, classify them in a different manner, for it is quite possible to have materials which give similar results under static loading and yet behave very differently under impact tests.

Although there cannot be any doubt of the importance of impact tests in affording an element of value in determining the properties of a material to resist stress, yet there is a considerable difference of opinion as to the exact nature of the information afforded, and this is hardly surprising when the number of variables is considered which enter into the problem.

The various machines designed for impact-testing differ greatly in the manner and swiftness with which the load is applied and in the rigidity of the frame and clamping devices for the test specimen, while the form of the piece also varies very much, especially as regards the notch cut in it to fix the place of failure. These, and other, circumstances tend to explain why it is so difficult, at present, to correlate the results obtained in a complete and satisfactory manner.

An important element for consideration is the stress distribution produced under load in various standard types of discontinuity, and it is proposed to examine some simple cases here, and discuss their bearing on the problem.

It is evident, from other cases of discontinuity already described, that, within the elastic limit, the contour of the notch is of chief importance as regards stress concentration, and that whether the notch be subjected to bending or tensional stress, the salient facts will be much the same at the contour. There is, however, a considerable difference in the experimental difficulties, and very little to be gained in a preliminary inquiry by examining a notch under the former type of stress. In all these experiments, therefore, notches are cut of considerable size in a very wide plate of transparent material, and this plate is subjected to uniform tensional stress in a testing machine in order to find the stress at the notch contour and across the principal section through the line of symmetry.

To obtain symmetrical conditions about the line of pull a second notch is cut in the plate at the opposite edge.

In some standard forms used in impact testing the notch is of V form, with sides inclined at 45 deg., and with a definite radius of curvature at the apex.

Such a notch is shown on the accompanying Fig. 3A, 1 cm. deep, with a radius of $\frac{1}{4}$ cm. at the apex and cut in a plate 13 cm. wide. Under loads there is no great difficulty in measuring the distribution of stress at any point of a plate of this size, and when this is carried out along the minimum cross-section perpendicular to the line of pull, a measure of the general accuracy of the observations is obtained, since the value of $\int p \, dx$ along this line should be equal to the load registered by the testing machine.

The values of $p$ and the cross-stress $q$ in this case are shown in the accompanying diagram, Fig. 3B, from which it appears that the stress rises to a maximum of 1,100 lb. per square inch, accompanied by a cross-stress $q$, which is very small except near the ends, where a maximum value of about 200 lb. per square inch is reached at a distance of between 0·3 cm. to 0·4 cm. from the edge of the notch. The mean stress given by the testing machine is 230 lb. per square inch, while the integrated value of the curve of distribution corresponds to 240 lb. per square inch, or about 4·8 per cent. in excess. Assuming the correctness of the testing machine reading, the stress concentration at the notch is 4·78 times the average stress at the cross-section, and for an angular distance of about 30 deg. on each side of this, the stress at the contour does not fall below 4·40 times this value, but beyond this the stress falls rapidly to zero along the notch contour. If, however, the radius of the notch is decreased to $\frac{1}{16}$ cm., the maximum stress rises to nearly six times the mean stress, as Fig. 4 shows, while if the radius is very large, say 10 mm., the maximum stress is approximately 2·2 times the mean.

It seems evident from these experiments and others described below, that an impact test on a notched specimen affords a valuable means of discriminating between ductile and brittle material, for whatever be the radius of curvature at the apex of the notch in a ductile material, it acts primarily as an indicator of the place where fracture is to commence, but once plastic stress begins, its influence in maintaining the high stress concentration observed here must recede in importance, although it is quite possible its form may be a factor in the final result. In hard and brittle materials, however, the radius at the bottom of the notch is apparently a dominant factor, since the stress distributions observed here can suffer little change in type throughout, and when due allowance is taken of static breaking stress in tension, such materials must have a comparatively low impact value on account of the maintenance of the relatively high stress concentration.

As a discriminating test of quality, an impact test may possibly be too severe and good material may be rejected by it, since the radius of curvature of the notch is a factor of variable importance according as the material is or is not ductile. In very hard materials there seems good evidence for bringing this factor into account in grading materials by impact tests.

This is more particularly emphasised when tests under different conditions of notch form are considered, as, for example, in one of the Charpy type, in which all the conditions of experiment are exactly the same as before, with a notch 1 cm. deep rounded off at the apex by an arc of $\frac{1}{4}$ cm. radius, Fig. 5A. Measuring the general accuracy of the experimental values by a comparison of the average stress intensity of 282 lb. per square inch recorded by the testing machine with the integrated stress intensity curve A B of Fig. 5B, we find, in this case, a value of 289 lb. per square inch, or 2·48 per cent. in excess, with a maximum stress of 1,000 lb. per square inch at the notch contour, and a concentration stress factor of 3·54, very much less in fact than is afforded by the standard notch of the form used in Izod machines, and described above.

This difference in concentration of stress is even more noticeable when the notch is of rectangular cross-section, Fig. 6A, with angles rounded off to a radius of 0·2 cm. for a notch 1 cm. deep. In this case the mean stress of 230 lb. per square inch recorded by the testing machine agrees remarkably well with the mean value of 229 lb. per square inch afforded by the curve A B of stress distribution across the principal cross-section, Fig. 6B, and we now find the maximum stress at points in the contour where a tangent line makes a slight inclination to the line of pull. Its value is 640 lb. per square inch, and gives the low stress concentration factor of 2·78.

These results seem to show that the form of the notch in an impact test not only exercises a very considerable influence on the results, but any one type of notch may cause that influence to be exerted in a variable manner according to the material tested.

As a test it is undoubtedly complex and even more difficult to analyse in the beam form, and its simplification, if that were possible, would be a great advantage.

It might, for example, be worth while to examine the possibilities of an impact test specimen formed by drilling out a very large hole centrally placed in a flat tension member, since this form of discontinuity has been shown* to cause an approximately linear stress distribution across the minimum section with a maximum value at the inner contour, and a minimum at the outer contour, which is nearly, but not quite, zero. In hard materials, therefore, where the elastic stress distribution probably remains practically unchanged up to fracture, the maximum stress is very approximately twice the mean value, while in ductile materials, photo-elastic indications appear to show that the stress distribution becomes fairly uniform at fracture.

*Fig. 5a. STRESS DISTRIBUTION AT THE CONTOUR OF A NOTCH OF THE CHARPY TYPE.*

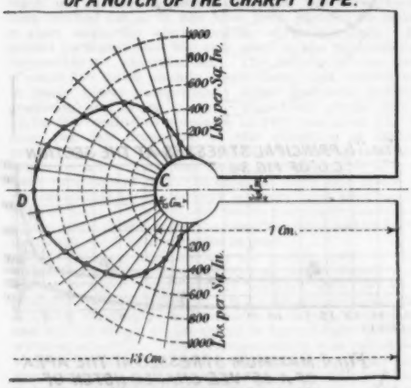



*Fig. 5b. PRINCIPAL STRESSES AT THE SECTION C.D OF FIG. 5a.*

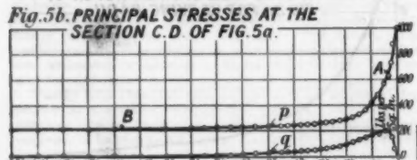



*Fig. 6a. STRESS DISTRIBUTION AT THE CONTOUR OF A STANDARD RECTANGULAR NOTCH WITH ROUNDED CORNERS.*

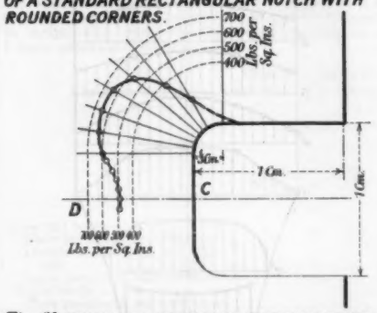
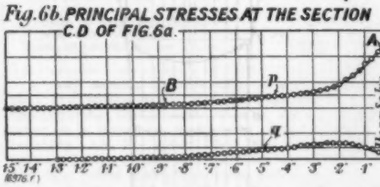



*Fig. 6b. PRINCIPAL STRESSES AT THE SECTION C.D OF FIG. 6a.*




## THE STUDY OF COALESCENCE IN STEELS, AND ITS COMMERCIAL RESULTS.*

By ALBERT PORTEVIN and VICTOR BERNARD (Paris).

### PART I.—FACTORS INFLUENCING THE PHENOMENA OF COALESCENCE.

*General Considerations.*—Coalescence is a universal phenomenon in alloys and consists of the fact that elements of structures of similar kinds, that is to say, belonging to the same phases, unite and agglomerate, thus giving rise to coarser elements. Besides this a very marked tendency may be observed, in the case of two or more phases, for the contours to become rounded, this leading to the assumption of the spherical form with its minimum of surface for a given volume, and so, in the case of the eutectic aggregates, to the globular, or spheroidal varieties. This dual aspect of the phenomena, increases in the size of the elements of a particular phase and tendency towards the spherical state, is characteristic of the tendency towards structural equilibrium, in which the phases of a complex material, instead of being formed of elements mutually disseminated throughout an aggregate, occur in continuous and distinct masses respectively in contact with one another. In mixtures of two phases coalescence takes place in the following sets of conditions which, on examination, bring out the elementary factors of the phenomena, enumerated later.

1. *At Constant Temperatures.*—Here only the variations in the intersolubility of the structural elements come into play in terms of the radii of their curves, their state of deformation, and their rate of diffusion in the solid state. Hence arises the fundamental importance of the part played by the original dimensions of the particles of the complexus, and by the state of internal stress. The latter factor does not obtain at high temperatures, which remove the internal stresses. As the rates of diffusion and of solution increase with the temperature, coalescence will take place the more rapidly in proportion as the temperature is higher. The temperature and the length of time are the variables of the problem.

2. *At Falling Temperatures.*—To the foregoing factors are superadded† the influence of the crystalline germ-forms, the heterogeneity of solid solutions, the variation —with the temperature—of the solubility, the faculty of spontaneous crystallisation, and the linear rate of crystallisation. As the crystalline germ-forms disappear gradually with increasing temperature the phenomena evolved will depend upon the antecedent states, besides which certain chemical elements present in minute proportions are able to play the part of catalytic agents in regard to the predominating chemical system. These latter influences are affected by the intervention of the following variables—chemical status and equilibrium diagram conditions, antecedent heat treatment (which may be characterised by the maximum temperature attained and the duration of heating), and rate of cooling or, more correctly speaking, the law of cooling. On the other hand, the directive influence which the crystalline environment exercises over the shape assumed by the structural elements while being deposited, helps to counteract the tendency towards the spheroidal form‡ at alternating temperatures (that is to say, during the alternations of heating and cooling about an equilibrium line in the diagram). Here, in addition, the rate of solution at rising temperatures intervenes, as well as the size of the antecedent structural elements, and to the foregoing variables must be added the law of variations in temperature, and in particular the number and amplitude of the alternations undergone.

*Results of the Influence of these different Factors on the Steel.*—These various factors lead to the agglomeration of the cementite of the steel in distinct rounded masses termed globular or spheroidal cementite. When, more particularly, this modification in shape affects the pearlite elements the latter is termed granular, or grained pearlite, to distinguish it from lamellar pearlite. This term appears to the authors to tend to confuse the issue, since the expression granular or grained structure has long been employed by mineralogists and crystallographers to designate the conglomerates of juxtaposed grains of crystalline elements. It is thus a term applicable to every crystalline mass composed of more than a single crystal, and thus to all metals, all alloys, and all holo-crystalline rocks. Therefore, in order to describe the rounded globular form of the pearlite elements, the authors prefer in future to employ the term "globular pearlite" (in contradistinction to lamellar pearlite) instead of the term "granular pearlite," which they, in common with all other writers on the subject, have hitherto employed.

In steels with a low carbon content (< 0·5 per cent.) the coalescence of the cementite reveals itself by the pearlite areas becoming bounded by a belt of partly formed cementite with the ragged edges which Osmond termed "atolls," from the analogy presented by these

* "Photo-Elastic and Strain Measurements of the Effects of Circular Holes on the Distribution of Stress in Tension Members," by Professor E. G. Coker, K. C. Chakko and Y. Satake. Trans. Inst. of Engineers and Shipbuilders in Scotland, Vol. lxiii, Part I.

* Paper read before the Paris meeting of the Iron and Steel Institute, September 6, 1921.

† See A. Portevin, "Principles and General Phenomena relating to Crystallisation, Solidification and Devitrification," *Revue Ingénieur*, 1921, vol. xxviii, page 165.

‡ A. Portevin, *Revue de Métallurgie*, 1919, vol. xvi, page 14.

irregularly shaped rings of cementite with the coral islets so named. These forms do not, however, occur in the eutectic and hypereutectic steels which the authors are about to deal with. The transformation of cementite lamellæ into globules involves an intermediate stage where strands of spherules occur. This is the "necklace" pearlite described by Benedicks* (who observed the phenomenon in a grey pig iron), which is similarly encountered in the very long and thin lamellæ of cementite in a high carbon steel superheated after a preliminary quenching (Hanemann and Morawe). An example of this appearance is given in Micrograph Fig. 2.

If now we take the case of the hypereutectic carbon steels we shall see that we have to distinguish between :—(1) The coalescence of the proeutectic cementite in the temperature zone comprised between Acm and A1, that is to say, in the region $Fe_3C$ + the solid solution of $\gamma$ iron-carbon, the solubility of the cementite varying considerably with the temperature in this region ; and

I. *For one and the same Steel.*

(*a*) Above A1.
1. Rate of cooling.
2. Temperature and duration of initial heating.
3. Temperature alternations about A1.

(*b*) Below A1.
4. Temperature and duration of maintenance at this temperature.
5. Previous mechanical working.
6. Original fineness of the cementite elements (troostitic or sorbitic states).

II. *For Different Steels* (the preceding factors remaining equal).
7. Carbon percentage.
8. Presence of elements other than carbon, such as, more particularly, chromium, tungsten and molybdenum.

The particulars relating to the part played by these various factors are not always in agreement, and are

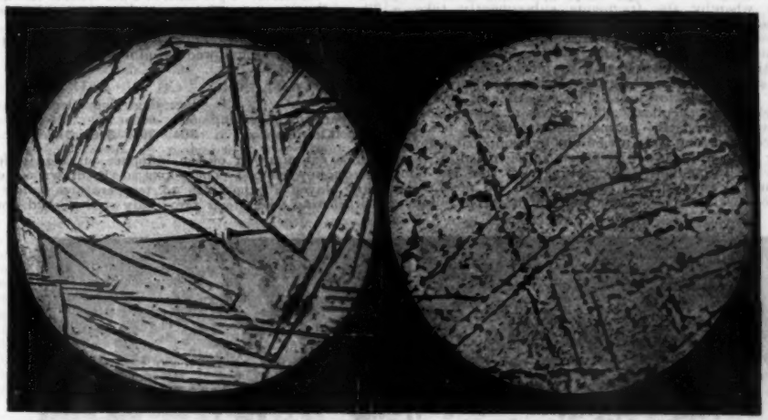


FIG. 1. ETCHED WITH SODIUM PICRATE. × 200.



FIG. 2. ETCHED WITH SODIUM PICRATE. × 200.

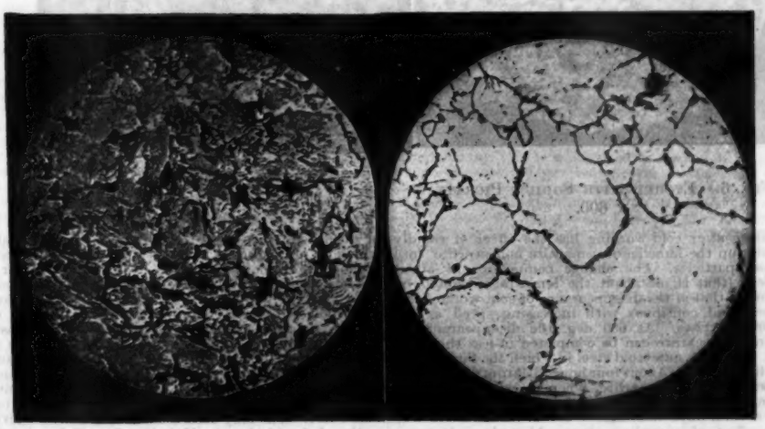


FIG. 3. ETCHED WITH SODIUM PICRATE. × 200.



FIG. 4. ETCHED WITH SODIUM PICRATE. × 200.

(2) the coalescence of the eutectic or pearlite (?) cementite at temperatures below A1, that is to say, in the region *a* iron + $Fe_3C$, the solubility of the cementite being in this case practically nil and independent of the temperature†. This distinction drawn, the authors will now investigate the influence, on the coalescence of cementite, of various elemental factors which are the results of the known general laws of solubility and of crystallisation, and which may be enumerated by passing in review the experimental researches on the formation of globular cementite by Hanemann, Morawe, and Lindt, by Howe, Levy, Whiteley, Honda and Saito, by the present authors, and by still earlier observers such as Stead, Arnold, Osmond, Lange, Law, Ischewsky and Belaiew.

From the general remarks made it is easy to see that the effect of the different factors is entirely different both in kind and degree according as the temperature zone is above or below A1, so that by limiting consideration to those only which are beneficial and appreciable in each instance it is possible to reduce their incidence to those summarised as follows.

* *Revue de Métallurgie*, 1909, vol. vi, page 567.

† In reality the solubility cannot be actually nil ; it is exceedingly feeble, and insufficient for representation on the scale of the equilibrium diagram. That solubility exists is a deduction from phase law, and from the very fact of the existence of coalescence phenomena, sometimes even contradictory, according to their authors. This, in the present authors' opinions, arises from the fact that, consciously or unconsciously, certain of these factors have been overlooked by some of the observers whose attention has been too exclusively devoted to those which, in their opinion, had the greatest influence on the result. It would appear necessary therefore to take into consideration the whole of these factors, and that this course is indeed indispensable in order to take into purview the totality of the conditions under which the coalescence of cementite can be either stimulated or destroyed. The importance of this operation will be seen in the second part of the present paper, where the effects of coalescence on the properties and heat treatment of steels are investigated. The authors will therefore briefly collate the various data actually in their possession, adding thereto the fresh results of their own personal observations.

1. *Rate of Cooling.*—Slow cooling favours coalescence within the zone of transformation Acm–A1, and during the passage through A1, that is to say, when the solubility of the cementite varies. To lower the rate of cooling is equivalent to prolonging the period of annealing at different temperatures (Howe and Levy). This equivalence persists, obviously, below A1 ; but as will be seen later very prolonged periods of annealing are required to cause appreciable phenomena within this zone, so that the effect of the slowness of cooling thus becomes practically negligible, particularly if it be practically comparable with the slowness of cooling while passing through A1. In regard to the latter consideration, Hanemann and Morawe have given the rate of 2 deg. per minute as the upper limit of the formation of globular pearlite in a eutectic steel ; in hypereutectic steels this globular pearlite is even more easily obtained that is to say, with higher rates of cooling, owing to the part played by the pro-eutectoid cementite in retarding the action, so that in the case of steels containing 1·3 per cent. of carbon and over, this effect is so intense that it is necessary to have recourse to air cooling on small samples in order to obtain lamellar pearlite. Thus hypereutectic steels annealed under ordinary conditions possess, as a general rule, a granular structure. This rule, however, does not take into account the influence of the original heating temperature, and if the latter has been high enough to lead to the complete solution of the cementite these conclusions are no longer valid. This effect of the original temperature will be discussed later ; the authors will limit themselves, in this connection, to pointing out that if the rate of speed during the passage of A1 were the only determinant all eutectic or hypereutectic steel ingots in their freshly cast state would have a globular pearlite structure, whereas, on the contrary, the pearlite, as is well known, is, in such ingots, lamellar.

The various appearances resulting from the coalescence of pro-eutectic cementite on annealing may easily be observed in a single experiment by starting, as the authors have done, with a highly cemented sample which allows of the simultaneous observation of the whole series of structure changes. In the original sample, the outer and highly carburised zone shows cementite in coarse needles (Micrograph Fig. 1, Widmanstaetten structure), which changes gradually to a cellular redistribution owing to the decrease, with the diminishing carbon content, of the dimensions of the original grains of the solid $\gamma$ iron-carbon solution in which the cementite has originated.* If a steel be subjected to an annealing at 900 deg. (annealing for four hours followed by a cooling extending over seven and a-half hours) it is found that the following sequence of appearances occurs :—(1) The needles (in reality, plates) of cementite are broken up into elements whose edges are rounded and whose threadlike arrangement reveals their origin ; (2) the network breaks up similarly into elements tending toward the globular form, but the differential distribution of which similarly reveals the origin, Fig. 3 ; (3) in the less highly carburised but nevertheless still hypereutectic areas the network is not appreciably altered (Micrograph Fig. 4).

2. *Temperature and Duration of Heating above A1.*—The heating of a hypereutectic steel to above Acm, that is to say, within the region of solid solution, leads to the solution of the cementite, and this result is the more speedily attained in proportion as the temperature is higher, so that increase in the temperature and duration of heating lead to the disappearance of the free cementite and of the ultra-microscopic particles which tend to act as a lag on the crystallisation, and to secure homogeneisation in the carbon content of the solid solution. These causes impede therefore the ultimate coalescence of the cementite,† a fact of which the ingots as fresh cast, and referred to earlier, afford evidence.‡ In further confirmation of these facts may be adduced the instances of case-hardened irons and steels maintained for long periods at high temperatures, which, despite exceedingly prolonged cooling (extending over several days) show, side by side with cementite coalesced into elements visible to the naked eye, pearlite showing, here and there, a lamellar form, but in highly developed plates recognisable under very small magnifications.

The authors have likewise observed that by heating the sample of case-hardened steel referred to above up to 1,300 deg. or 1,400 deg. and letting it cool very slowly, the whole of the pearlite remains lamellar, whilst the point A1 is being passed at a rate of 0·3 deg. per minute, which is very different from the limits assigned by Hanemann and Morawe. Numerous other instances could be quoted, but these would appear to suffice. K. Honda and S. Saito have heated a series of steels with variable percentages of carbon by maintaining them for 20 minutes at various temperatures and then cooling them slowly (without, however, stating the rates of cooling). They have observed in hypereutectic steels that coalescence of the cementite occurs at all temperature comprised between Ac1 and a temperature which increases with the percentage of carbon in the following way :—

| Percentage of carbon ... | 0·80 | 1·20 | 1·50 (and over) |
|---|---|---|---|
| Highest temperature of coalescence ... ... | 750 deg. | 780 deg. | 850 deg. |

Above the latter limits the lamellar pearlite reappears on cooling.

The influence of the temperature and the duration of heating on the coalescence during cooling often appear to be unknown in industrial practice, particularly after a softening annealing for ball-bearing steels containing 1 per cent. of carbon and 1 per cent. to 2 per cent. of chromium, the treatment of which should lead to the

* It is known that, heating conditions being equal, the size of the grain of the solid $\gamma$ iron-carbon solution increases with the carbon content (Howe), and that the intergranular distribution (Widmanstaetten structure) is the more readily attained, under equal cooling conditions, in proportion as the initial grains are more fully developed.

† These causes are the same as those which, for the same reasons, retard the critical rate of hardening.

‡ Other examples of this micrography of lamellar pearlite in steel ingots as cast will be found in Dalby's investigations. ENGINEERING, 1917, April 6, "Strength and Inner Structure of Mild Steel."

production of globular cementite. It might sometimes be thought that the end might be sought by intensifying both the conditions accompanying annealing, temperature of heating and slowness of cooling, and thus the authors have observed at certain works the practice of heating up to 900 deg. for six to seven hours, followed by a cooling extended over 60 hours before reaching 400 deg. to 500 deg. The results have been deplorable, whereas a heating of 6 to 15 hours at only 750 deg., followed by cooling, over a period of about 10 hours to 500 deg. would have been much better. From the influence of these two factors emerges, as a direct consequence, the influence of the rate of heating. Coalescence (and therefore the resultant softening of the steel) is a function of the rate of heating, particularly in the region immediately below Ac1, as has been found in the case of the ball-bearing steels referred to.

3. *Alternations of Temperature during the Passage of A1.*—This provides one of the best modes of securing the coalescence of the cementite. During the periods of heating the tiny particles of cementite disappear, both because of their minute dimensions and their greater solubility, while, during the periods of cooling, the dissolved cementite precipitates on the residual particles, the dimensions of which grow accordingly. Osmond had already pointed out this method and drawn attention to the analogy it presents with that employed to obtain large crystals from saline solutions. In both instances the phenomena result from the same mechanism. Micrograph Fig. 5 shows the result of three temperature alternations between 750 deg. and 700 deg. on the steel, the initial state of which is shown in Fig. 1. It will be seen that coalescence is much more pronounced than in Fig. 2, although there may still be distinguished the arrangement of the original needles of cementite. In such greatly prolonged heating could have been carried out in a platinum resistance furnace, in which rigorous control of the temperature (unless an absolutely constant current supply be available) is an exceedingly delicate matter, without the Ac1 point having been exceeded. The authors have carried out analogous experiments on hypereutectic steels with well-developed pearlite lamellæ, unworked, and kept for 10, 30, and 50 hours at 700 deg. in a salt-bath furnace. Coalescence is but feebly marked, and well-formed lamellæ are found persisting even after these various treatments (Fig. 7). On the other hand, on eutectic and hypoeutectic steels as rolled, and heated for 50 hours at 700 deg. in salt-baths, the authors* have obtained complete disappearance of the lamellar structure. They will deduce their conclusions after having examined the influence of the remaining factors.

5 and 6. *Preliminary Mechanical Treatment; State of Division of the Cementite Elements; Effect of Forging.*—We have seen that the coalescence of the cementite into large plates takes place by a preliminary breaking down whereby the fragments subsequently take a globular form while remaining arranged in strands. The process will therefore be facilitated if this preliminary breaking up of the lamellæ of the proeutectic and eutectic cementite be effected by mechanical means or even simply by deforming them when hot (forging) or when cold (cold-working). The experiments of J. H. Whiteley are peculiarly illustrative of the effect of cold-working on the formation of globular pearlite. This cold-working was carried out by hammering down, under a steam-hammer, steel bars so as to reduce their diameter by one-half, while taking care that the temperature attained during the operation did not exceed 100 deg. His conclusions can be summarised as follows: Annealing after cold-working has the effect of rapidly breaking up the lamellæ of cementite and pearlite into spheroid particles. The change commences at about 500 deg. (that is, at about the temperature noted by Goerens as that of the disappearance of cold-work effects in steel) and continues with increasing speed as the temperature rises. At 680 deg. the disappearance of the lamellar pearlite can be completed in less than two hours, even in a eutectoid steel in which the lamellæ are exceedingly thin. About four hours' heating are required for the very coarse pearlite, whereas, with a steel not previously cold-worked, this result cannot be attained under several days' heating.

The effect of annealing after cold-working becomes clearly manifest if the modifications of structure resulting from cold rolling and successive annealings on the same 1·2 per cent. carbon steel sheet be examined, as was done by Hanemann and Lindt. It was found that each annealing following a rolling accentuated the coalescence of the cementite. The steel, which, after the first annealing showed a structure of lamellar pearlite and sorbite, consisted entirely of globular pearlite after two rollings and two reheatings. The cementite globules continued to grow as the treatments were persisted in. Whiteley was unable, after the closest examination, to detect the slightest trace, after cold-working, of any rupture of the lamellæ of pearlite cementite, and recalls Howe and Levy's experience of the very great flexibility of these lamellæ in their experiments on the plastic deformation of pearlite, a flexibility which is not surprising in lamellæ so exceedingly thin, inasmuch as the elastic deformation of bending increases inversely as the cube of the thickness. Permanent deformation and even, as Professor H. Le Chatelier has pointed out, elastic deformation, suffice to vary the solubility of the cementite, and therefore, in accordance with the general views referred to in the introductory paragraphs of the present paper, its reaction on the phenomenon of coalescence. It may, in addition, be added that even if the deformation of the cementite lamellæ be purely elastic that of the ferrite must of necessity be permanent in any plastic deformation of the whole. The cold-working of the cementite alters the mutual intersolubility of the complex, ferrite-cementite, which is the factor to bear in mind. It is, similarly to the variation in solubility—a function of the radius of the curve—that the influence on coalescence of the fineness of the cementite elements is to be attributed. The spheroidisation of the cementite is distinctly intensified if troostite or sorbite be previously present, and if, therefore, the steel has been previously hardened.* On this point all the observations agree; the result is completely comparable with that obtained by preliminary deformation. It is to this double influence of the plastic deformation and the fineness of structure that must be attributed the greater aptitude towards coalescence which has been observed and recorded when untreated forged steels are taken. In addition to the forging the air cooling which follows leads, generally speaking, to the partial formation of troostite. This acceleration of coalescence by the influence of forging is such that it reveals itself on examination by variations in hardness, even after relatively very short periods of heating, in the case of steels in which coalescence is difficult, such as steels with 1 per cent. of carbon and 1 per cent. to 2 per cent. of chromium. The following examples are taken from the results obtained on a steel of this composition, as forged, and kept, for 10 minutes only, at different temperatures, the heating being followed by oil immersion:—

| | | | Ac1. | | | |
|---|---|---|---|---|---|---|
| | deg. | deg. | deg. | deg. | deg. | deg. |
| Temperature of heating | 500 | 600 | 700 | 725 | 750 | 775 |
| Brinell hardness ... | 364 | 364 | 340 | 315 | 444 | 652 |

The examination of the influence of these different factors now enables conclusions to the drawn as to the part played by heatings to temperatures below A1. (*a*) Starting with steels previously cold-worked, forged or quenched, coalescence becomes manifest for heatings which do not exceed A1, and is the more pronounced in proportion as the temperature of heating is higher and the duration more prolonged. It is not really appreciable until the Ac1 temperature is approached; (*b*) starting with annealed steels containing lamellar pearlite, coalescence below A1 is only perceptible in the case of extremely prolonged periods of heating, so that in such instances the influence of this factor may be disregarded.

In any case the rate of cooling below A1 has practically no effect, with the result that a coalescence treatment can be ended by rapid cooling once the temperature has fallen below Ar1. The only consideration that need intervene in the choice of the rate of cooling is, as pointed out by Howe and Levy, that of the residual internal stresses.

7 and 8. *Chemical Composition of the Steel (percentage in Carbon and in other Elements).*—The programme of experiments undertaken by the authors with a view to ascertaining the influence of the chemical composition of steel upon the phenomena of coalescence has only been begun, having been interrupted in 1914 and the tests not having been recommended since. While awaiting the opportunity of collating data on this subject the authors must remain content to recall the following points. The difficulty of effecting coalescence of the cementite is greatest in the case of the eutectic composition.† In the case of the hypereutectic steels the readiness to coalesce increases with the carbon percentage, and this phenomenon is a constant in all annealings of such steels carried out within the range of transformation. Low percentages of chromium and of tungsten render the coalescence of steels containing 1·0 to 1·2 per cent of carbon more difficult. This is well known in connection with ball-bearing steels. A steel containing 1·2 per cent. of carbon, 0·5 per cent. of tungsten, and 0·5 per cent. of chromium displayed a barely appreciable

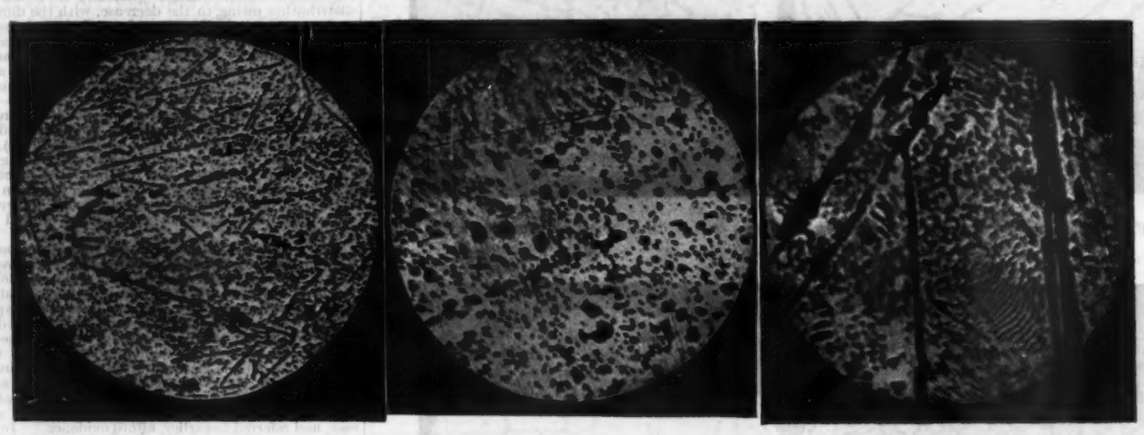


FIG. 5. ETCHED WITH SODIUM PICRATE. × 200.

FIG. 6. ETCHED WITH SODIUM PICRATE. × 600.

FIG. 7. ETCHED WITH SODIUM PICRATE. × 870.

Fig. 6, which represents a less carburised zone subjected to the same treatment, every trace of the original structure has disappeared.

It may be said that every alternation of temperature about A1 diminishes the number and increases the size of the cementite elements.

4. *Temperature and Duration of Heating below A1.*—Opinions are divided as to the influence of these two factors. Of the different observers, one group (Goerens, Hanemann and Morawe, Howe and Levy, &c.) agree that there is, in all instances, coalescence of cementite as the result of prolonged heating below A1, the phenomena taking place the more rapidly in proportion as the temperature—while still remaining below A1—is higher. On the other hand, Honda and Saito consider that the coalescence of lamellar cementite can never occur unless Ac1 is reached, but that, if sorbite be present (if, that is, a hardened sample be taken) cementite coalescence occurs.

These divergent views arise, in the authors' opinion, from the differences in the experimental conditions and the difficulty of accurately determining the annealing temperature in relation to A1. The latter point is known only by its manifestations Ac1 and Ar1, which occur respectively on heating and on cooling, and it depends on the rates at which the temperature varies, so that if Ac1 be approached as closely as possible in order to stimulate the phenomenon of coalescence there is a danger of exceeding it. Now it is beyond doubt that one of the most efficacious means of obtaining globular pearlite is to effect the A1 transformation slowly during cooling, and that there is therefore a danger, on endeavouring to maintain a sample in the neighbourhood of this point, of this mode of action, and of alternations of temperature (which are eminently favourable to the occurrence of coalescence) taking place.

The negative results (those of Honda and Saito) relate to periods of heating extending for 20 minutes up to 12 hours, that is to say, relatively short times, whereas the positive results have been deduced from greatly prolonged periods of heating. Hanemann and Morawe, for instance, report the breaking up of the cementite lamellæ after annealing for 35 hours at 685 deg. and their complete disappearance after being maintained for 1,062 hours at this temperature. It is not possible, therefore, to compare these experimental methods, and the coalescence of lamellar pearlite below Ac1 ought to be accepted as a fact, if it be allowed that

* A. Portevin and V. Bernard, Journal of the Iron and Steel Institute, 1914, No. II, page 204.

* It is necessary to point out in this connection the method of operating, often attended with success, for softening the self-hardening nickel-chromium steels, which consists of giving an oil-quenching previous to the ordinary heating up to just below Ac1.

† Howe and Levy. This fact may be co-ordinated with that of the minimum critical rate of hardening (Portevin and Garvin), as they both have the same origin, the reduction in the retarding effect on the crystallisation of the cementite.

degree of coalescence when subjected to a treatment which had caused complete coalescence in a tool steel with 0·98 per cent. of carbon. The Brinell hardness remained 220 in the first instance, whereas in the second it fell to 136. On the other hand higher percentages of chromium, tungsten, and molybdenum cause complete coalescence of the carbon. The necessary percentages to ensure this result diminish, for a given treatment, with the carbon percentage. All the carbon then occurs in the globular form observed by Osmond in chromium steels, and presents the micrographic appearance termed "double carbide," which is a structure identical with that of coalesced hypereutectic steels. Having thus a knowledge of the various factors which influence the formation of globular cementite, their relative importance and the direction in which they act, it is easy to see how and to what extent it is possible in practice to obtain or to destroy coalescence of cementite in any particular instance, by means of certain tests, the sequence of which may be conceived from the particulars so obtained. Indeed, the task is one which can be entrusted to any trained operator.

*(To be continued.)*

## THE PRESENT STATE OF THE CARBONISATION OF COAL AT LOW TEMPERATURE.

IN spite of the enormous amount of work done recently on low-temperature carbonisation, both in Europe and America, the technical application of this system, with which we have dealt on many recent occasions, is still in its infancy. In a report presented lately to the American Gas Association, meeting at Chicago, on behalf of the United States Bureau of Mines, Mr. Joseph D. Davis, fuel chemist to the Pittsburgh branch of the Bureau, ascribed this slow development to three causes: Inadequate knowledge of coal constitution and thermal decomposition, the slow evolution of suitable retorting apparatus, and the non-existence of a market for the rather special distillation products of low-temperature carbonisation. Authorities differ as to the meaning of low temperature in this connection. While Bone recommends 550 deg. to 600 deg. C. as best suited to British bituminous coal, temperatures used also by the Fuel Research Board, and while Fischer and Gluud (Institut für Kohlenforschung) consider this range preferable for the production of primary tar (Urteer), the latter state also that the primary tar only begins to decompose appreciably at 800 deg. C., and S. W. Parr, converting Illinois coal into a smokeless domestic fuel, defined "low-temperature carbonisation as destructive distillation at temperatures not exceeding 750 deg. or 800 deg. C. Mr. David would not exceed temperatures of 750 deg. C. so as not to decompose the paraffins and tar acids. There is considerable diversity of opinion further as to the character and amounts of the by-products attainable; but bituminous coal may be said to yield about 10 per cent. of primary tar oils, consisting chiefly of phenols (up to 50 per cent. of the tar), hydrocarbons of the paraffin series (10 per cent. to 15 per cent.) and of naphthenes, hydro-aromatic and unsaturated compounds; 15 per cent. may be classed as lubricating oils boiling above 300 deg. C., and 9 per cent. as resins; as to these figures Gluud and Parr are in fair agreement. The coked residue will represent 70 per cent. to 75 per cent. of the coal, and will still contain up to 18 per cent. of volatile matter; like Fischer, Parr recommends a preliminary slow heating up to 300 deg. or 400 deg. The ton of coal should yield some 5,000 cub. ft. or 6,000 cub. ft. of a gas of 650 B.Th.U. to 570 B.Th.U., of which 27 per cent. will be hydrogen and 58 per cent. methane and higher members, 7·5 per cent. CO, and 2·5 per cent. $CO_2$.

As yet there is no well-established demand for the low-temperature products either here or in America. The coke is not suitable for metallurgical operations, but an ideal fuel for domestic purposes. Though low-temperature carbonisation can only be established on a sound commercial basis with low operating costs and a very moderate margin of profits, as Sir George Beilby put it in his James Forrest lecture last June, the fuel oils are very valuable. The 3 gallons of motor spirit, which the ton of coal may yield, require refining of the tar oils, however; that is at present done by oil-refinery methods, but other methods are being worked out at Pittsburgh and elsewhere. We mentioned recently that at the Barnsley plant a light oil complying with the Admiralty specification is produced by steam distillation. Tar acids are wanted for timber preservation. According to F. P. Coffin, the United States required nearly 100,000,000 gallons of such oils before the war, two-thirds of which were imported; the low-temperature oils seem better suited for this purpose than the ordinary creosote oils of gas works. The acid oils are also used as insecticides and disinfectants, and for ore flotation. The amount of surplus gas, available for distribution, is small; but the gas is of good quality and suitable for domestic heating. As regards the kinds of coal that can profitably be submitted to low-temperature carbonisation, semi-coking coals rank first. Sub-bituminous coal and lignite also lend themselves to this treatment, and these are receiving attention in the Western States of America, where high grade solid coal is scarce, and in Canada.

The difficulties of the retort design are mainly due to the low thermal conductivity of coal. In order to obtain uniform temperature, and to prevent local overheating, the engineer is restricted to low-temperature gradients and retorts of small dimensions. Mr. Davis recommends distillation under reduced pressure and recirculation of the gases to remove the vapours produced as rapidly as possible from the retorts; with recirculation the gases can give up some of their heat to the charge; but the latter process would involve stirring the retort charge, and technically both methods are difficult. The following summaries of processes recently proposed and tested, chiefly in America, are given in abstract from Mr. Davis's report.

*The Carbocoal Process.** A plant with a capacity 500 tons per day, based on this process has been in operation at Clinchfield, Virginia, for the past year and represents perhaps the farthest advance in commercial low temperature development in the United States. The carbocoal process includes three distinct stages: (1) Primary carbonisation, (2) briquetting, (3) secondary carbonisation.

*Primary Carbonisation.*—The coal to be processed is first crushed to ¼-in. size or smaller, and then fed into a horizontal retort through which it is forced continuously by heavy cast-iron paddles mounted on two parallel shafts. The retort is heated by gas at the bottom and sides to a temperature of 850 deg. to 900 deg. F. (450 deg. to 480 deg. C.). Uniform and rapid heating is in this case secured by agitation of the charge, and the fact that the solid residue obtained is thereby broken up is in no way objectionable since it is subsequently briquetted. The product of the low-temperature retorts is immediately mixed with 10 per cent. of pitch (obtained in refining the tar recovered in the process) and briquetted. The briquettes are then carbonised at 1,800 deg. F. (980 deg. C.) in inclined retorts. The yields of products reported for this process agree fairly well with low-temperature yields previously given, and it remains only to be said that the highly-refined briquettes obtained as the final product appear to be in good demand for domestic fuel.

*The Summers Retort.*—A continuous low-temperature retort designed especially for producing a dense coke by compressing the charge during coking has been proposed by Summers (communication received from the inventor, Mr. L. L. Summers, 140, Nassau-street, New York City, N.Y.), and a plant designed on these lines is being erected at Hamsburg, Ill. Briefly, the Summers' retort consists of a horizontal coking chamber built of masonry about 40 ft. long, and of rectangular vertical section, 17 in. wide by 27 in. high. On the floor of the retort is a reciprocating iron conveyor extending throughout the retort length. A heavy cast-iron fin attached to this conveyor serves to take the raw coal from a hopper at one end of the retort and force it forward toward the other end, where it is discharged through a water seal as coke. The conveyor is actuated by a powerful hydraulic ram. Heating is effected in large flues running horizontally through the retort side walls, and built-in regenerators are provided at the top. Extending along the roof of the carbonising chamber is a channel which serves to assemble the distillation vapours and convey them to a standpipe and hydraulic main located at the feed end of the chamber. Provision is made for shifting the zone of highest temperature to any desired section of the oven walls so that the heating of the charge can be well controlled.

Mr. Summers states that "domestic coke of unusual density or metallurgical coke can be made if desired." This is particularly interesting, since it lays open the possibility that in the future, low-temperature coke of such quality may be made that it will compete with that from high-temperature processes. The yield of oil (20 gallons per ton) is much greater than that obtained in high-temperature processing, and at the same time a large yield of good gas is realised, 1 ton of coal yielding 8,000 cub. ft. to 10,000 cub. ft. of 590 B.Th.U. to 630 B.Th.U. gas. It would seem, however, that in view of this high gas yield, distillation temperatures above the low-temperature range were maintained and that the tars must have been decomposed to some extent.

*The Green-Laucks Retort System.*—An experimental plant (*Coal Age*, vol. xv, page 810, 1919), of the Green-Laucks system, is operated at Denver, Colorado, by the Denver Coal By-Products Company. The retorts are vertical, 18 in. in diameter and 18 ft. high, four retorts being mounted in each setting. A hollow worm mounted axially in each retort serves to force the charge through it and at the same time to conduct the distillation vapours to the outside. A vacuum as high as 24 in. of mercury has been maintained in the retorts. This system involves, therefore, some agitation of the charge, and in addition, distillation under reduced pressure.

*The Wallace Retort.*—The most interesting feature of this retort system is a perforated off-take located at the centre of the retort, the idea being to insure passage of the vapours from the point of evolution in a direction opposite to that of the heat flow. The Wallace retort consists of a cast-iron cylinder mounted vertically in a brick setting, and is heated by combustion gases in a annular combustion chamber passing entirely around the retort. To the top and bottom of the retort are bolted cast-iron plates, the joints being made gas-tight with asbestos gaskets. The perforated off-take pipe is closed at the top and passes downward through the centre of the retort and to the outside through the bottom plate. Provision is made for collecting the tar oils that condense in that portion of the off-take which is inside the retort, so there is little chance for the oils to become superheated. According to a communication from Mr. G. W. Wallace (Wallace Coke, Oil and By-Products Company), a Wallace plant at Petersburg, Virginia, has very recently been put into operation. All the analyses of products for the preliminary runs are not yet available, but it appears that the coke obtained is of good quality, the gas yield abnormally high, and the oil yield perhaps somewhat low.

*The Stansfield Carboniser.*—In a continuous apparatus for carbonising lignite evolved by Stansfield (Stansfield Edgar, Carbonisation of Canadian Lignite, J. Ind. and Eng. Chem., vol. xiii, No. 1, January 1, 1921, page 17), the material is fed on to the floor of a rectangular retort inclined at an angle of 35 deg., or slightly greater than the angle of repose of crushed lignite. The retort floor is gas-heated from below and the charge flows over it by gravity, the thickness of the layer being fixed by numerous baffles placed at right angles to the floor. The baffles also effect stirring of the charge and uniform heating. The rate of flow of material through the retort is regulated by the rate of withdrawal of carbonised lignite at the lower end of the retort.

*The Traer Retort.*—Traer (Traer, G. W., "Low-Temperature Distillation of Illinois and Indiana Coals," Bull. Am. Inst. Min. Eng., vol. cxli, 1918, page 1463) carbonises coal continuously in a retort 60 ft. long, and of rectangular section, 20 in. wide by 48 in. high. The charge is carried through the retort in cast-iron boxes mounted on iron cars, with which the retort is kept filled, freshly-charged cars being fed in at one end and cars of coke being removed at the other. Each end of the retort is fitted with a double door system. Passage of heat to the charge is here aided by the high conductivity of the iron containers.

The same device is used by the British Fuel Research Board (Lander, Cecil, discussion of Professor Bone's paper on "Low Temperature Carbonisation," *Gas World*, vol. lxxv, No. 1,929, July 9, 1921, page 34) to obtain efficient heating in their experimental low-temperature retort. Here the coal is charged in shallow iron trays subdivided by numerous partitions, and the coked residue is obtained in uniform size.

*Gas Generators with Built-in Low-Temperature Carbonising Retorts.*—A method of combining low-temperature carbonisation with complete gasification of coal has been developed in Germany and is now, according to Gluud of considerable industrial importance. The apparatus is being built by the A. G. für Brennstoffvergasung, Berlin, N.W., 40 Roonstr 4, and also by the Deutsche Mondgas u. Nebenprodukten Ges., m.b.H., Berlin. The machine of the Brennstoffvgergasung Company is an ordinary gas producer with a rotating top. Attached to this is an annular iron retort extending downward into the body of the generator with means provided for retaining the charge and feeding it uniformly over the surface of the fuel bed in the generator as carbonisation is completed. A hopper, similar in design to the charging bell of a blast furnace, serves to admit fresh coal as required to the retort. The retort is heated partly from the outer surface by conduction from the hot generator gases and partly by direct contact with a portion of the generator gas which is drawn through it. About one-third of the generator gas is by-passed through the retort for this purpose, and after the usual scrubbing for low-temperature oils it is reunited with the main supply which comes directly from the generator. It is claimed that the loss of gas due to pre-carbonising the coal can be replaced with an additional 10 per cent. of raw coal or oven less.

The improved Mondgas machine has a bell-shaped, low-temperature retort built into the stationary generator cover and extending vertically downward into the generator body. The heating is done in the same manner as in the machine of the Brennstoffvergasung Company just described. Stirring of the charge and a uniform feed of coked residue are maintained by means of a gear-driven stirrer and distributor mounted axially in the retort. With this arrangement, coking of the coal is completed in 2½ hours and the generator gas contains "hardly any traces" of tar; whereas without stirring the charge the coking time is 3½ hours, and even then the generator gas is dirty. The gases were compared for two parallel runs with brown-coal briquettes; the low-temperature retort being operated in the one test and not in the other. In the latter test 9 per cent. more gas was obtained, but it contained more tar and water, 80 grammes of water and 5 grammes of tar per cubic metre; whereas in the other test the total gas obtained from the generator and low-temperature retort contained only 30 grammes of water and 3 grammes of tar per cub. metre. The heating value of this gas was about 1·5 per cent. higher than that of the gas obtained by direct gasification. A clean, dry gas is always to be desired, and it does not appear that the scrubbing of the gas in this process presents much difficulty. Furthermore, it is only necessary to scrub one-third of the gas produced. The process might even prove applicable to lignites in the Western States.

*Conclusions.*—Although increased interest has been manifested in low-temperature carbonisation during the past year, progress toward commercial development has been slow. This is probably due in part to market conditions, and in part to difficulties experienced by builders in perfecting their apparatus mechanically.

In order that a low-temperature industry may be firmly established, it is necessary that the popular prejudice against soft coke be overcome, and it will take time to accomplish this.

It does not appear that low-temperature methods are destined soon to occupy an important place in the gas industry in so far as gas for city supply is concerned. They may, however, be used to advantage in the production of industrial gas.

* This process was fully described and illustrated in ENGINEERING, vol. cxii, page 175.

AMERICAN OBSERVATORY IN QUEENSLAND.—Great scientific interest attaches to tests now being made in Queensland prior to the selection of a site for an important observatory to be established there by Harvard University, U.S.A. Provision was made by the State Government to enable the tests, which are under the direction of the Surveyor-General, to be carried out. Four sites, located as follows, are being tested—Mount Gowrie, Table Top Mountain, Square Top, on the Darling Downs, and Mount Mowbullan.

# "ENGINEERING" ILLUSTRATED PATENT RECORD.

## SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACTS OF 1907 AND 1919.

*The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.*

*Where inventions are communicated from abroad, the Names, &c., of the communicators are given in italics.*

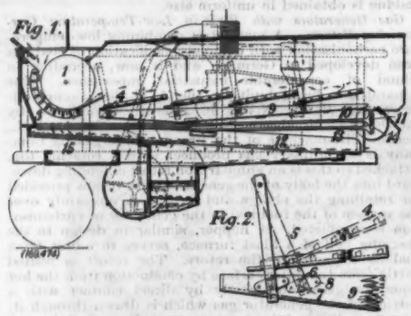
*Copies of Specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery-lane, W.C., at the uniform price of 1s.*

*The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.*

*Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.*

### AGRICULTURAL APPLIANCES.

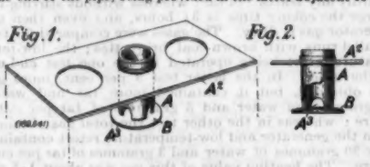
**169,474. Ransomes, Sims and Jefferies, Limited, Ipswich, and A. Girling, Ipswich. Threshing Machines.** (3 *Figs.*) April 24, 1920.—The invention relates more particularly to the mechanism for actuating the straw shakers. According to this invention, a plurality of straw shakers is employed, each being fixed to and carried by a hanger pivoted at one end and engaged at the other end by a jog shoe. 1 is a rotating drum and 3 is the concave between which and the drum 1 the sheaves are passed to effect the separation of the grain from the straw. The straw passes to shakers 4, each of which is fixed on each side




to a hanger 5, pivoted at its upper end to the machine. Each hanger 5 has at its lower end a case-hardened pin 6, which engages in a slot 7 in a casting 8 fixed to a jog shoe 9 to which reciprocating motion is imparted by means of a connecting rod 10 and a crank-pin 11. The jog shoe 9 forms a collecting tray which delivers grain, chaff, and short straw to a riddle 15. The grain, together with the chaff and other impurities, falls on the inclined floor of a second shoe 12, to which reciprocating motion is imparted by a connecting rod 13 and a crank-pin 14. (*Sealed.*)

### ELECTRICAL APPARATUS.

**169,541. Saunders Electrical Company, Limited, Coventry, and C. Saunders, Coventry. Electrical Accumulators.** (2 *Figs.*) July 5, 1920.—According to this invention, the vent pipe A extends substantially vertically into the interior of the cell from the upper wall $A^2$, to which it is permanently secured, and has its inner end closed by a baffle B which projects radially around the pipe, lateral orifices, formed by notches $A^3$ in the end of the pipe, being provided in the latter adjacent to the



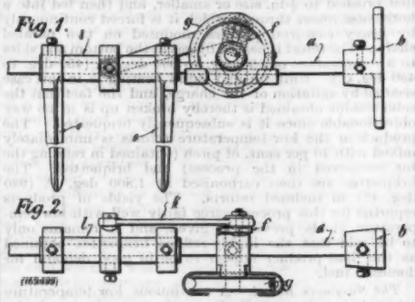

baffle. The baffle B is convex on its upper surface and concave on its lower one, such formations permitting splashings from below, as well as drops of moisture on upper parts of the pipe, to drain to the edges of the baffle, and thus return to the main body of liquid. The arrangement also permits of pouring the liquid into the cell through the vent pipe without difficulty, and the position of the lateral orifices avoids trapping any liquid in the pipe. (*Accepted October* 12, 1921.)

### MACHINE AND OTHER TOOLS, SHAFTING, &c.

**168,615. A. C. Couldwell, South Norwood, London. Milling Tools.** (5 *Figs.*) January 12, 1921.—The invention relates to milling tools of the kind comprising a cylindrical body having helical grooves in its periphery in which the cutters are held in spaced relationship by distance pieces inserted in the grooves between the cutters. The helical grooves *a* in the body

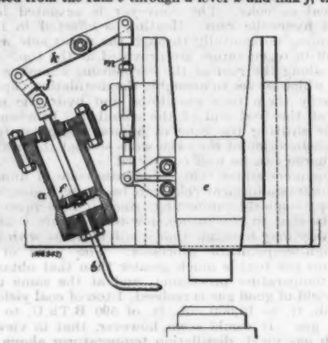
of the tool are, according to this invention, dovetail in shape, and the root of each cutter *c* is of similar shape. Dove-tailed distance-pieces *d* are arranged between the cutters. The cutters in one groove are in staggered relationship to those in the next groove. The cutters are held in the grooves by a circular plate *e* screwed on to each end of the body *b* of the tool. As additional means of holding the assembled cutters and distance-pieces in place, a flat spring *i* is located in an undercut portion *j* of the body *b* with one of its ends under the root of the end tooth *c* and its other end pressed downwardly by a grub screw passing through from the outer circumference of the body of the tool. (*Sealed.*)

**169,499. F. G. Perris, Brooks Bar, Manchester, and H. M. Darrah, Manchester. Belt Forks.** (4 *Figs.*) June 23, 1920.—According to this invention, the forks proper *c* are mounted on a tubular member *i* so as to be capable of angular adjustment, and the tubular member *i* is mounted to slide on a guide bar *a* provided with a bracket or brackets *b* by means of which it may be carried from any suitable fixture. The tubular member *i* is reciprocated by a crank arm *f* operated from a rope-driven




pulley *g*. The stroke of the crank arm is adjustable so that the traverse of the forks can be adjusted to accommodate pulleys of different widths. The shifting mechanism is preferably adapted to be changeable from one end of the bar *a* to the other, and the point of connection of the connecting link *h* and tubular member *i* is also preferably adjustable to allow of the stroke of the forks taking place at different points along the length of the bar *a*. (*Sealed.*)

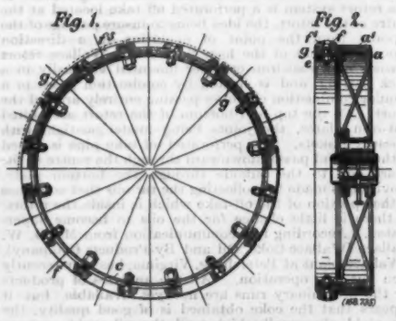
**168,942. T. H. Webb, Wakefield and C. J. Rhodes, Wakefield. Power Presses.** (1 *Fig.*) May 7, 1920.—The invention relates to power presses of the type in which the article is removed from the tool by a blast of air created by operation of the mechanism and comprehends apparatus for removing the stampings from the dies consisting of a pump *a* operated from the ram *e* through a lever *k* and link *j*, the latter



being coupled to the pump piston *f*. The lever *k* is coupled to the ram *e* by a link *m* in which is an adjustment member consisting of a turnbuckle *o* having right and left-hand screw-thread connection with the link *m*. The effective length of the link *m* can thus be adjusted. The upward movement of the ram *e* effects the power stroke of the pump, during which the air in the pump cylinder *a* is compressed and delivered through the conduit *b* towards the die. (*Sealed.*)

### MOTOR ROAD VEHICLES.

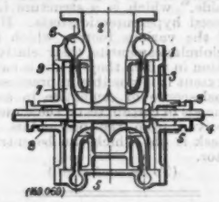
**168,735. John Fowler and Co. (Leeds), Limited, Leeds, J. Robinson, Leeds, and H. Hodgson, Leeds. Road Wheels.** (5 *Figs.*) July 9, 1920.—Road wheels for traction engines, tractors and other mechanically-propelled vehicles, in accordance with this invention, comprise an ordinary wheel *a* having a tyre *a*1 of metal or other hard material, either with a plain rim or faced with cross bars, and a rim or annulus *s* secured




to or integral with the ordinary wheel *a*, the rim or annulus being provided with one or several sectional tyres *f* of rubber or relatively soft material of normally greater diameter than the tyre *a*1. The tyre *f* is formed of a number of peripheral sections secured to the rim or annulus *s* as by bolts, packing members *g* being provided for insertion between the rim *s* and tyre sections when the latter become worn to an ineffective depth. (*Sealed.*)

### PUMPS.

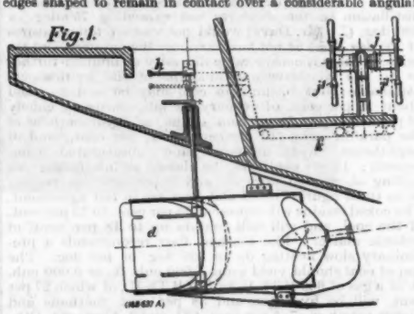
**169,069. C. M. Cherrie, Newton. Centrifugal Pumps.** (6 *Figs.*) July 26, 1920.—The invention relates to centrifugal pumps which operate against a vacuum or suction head. Two single suction impellers 3, 3 are mounted on the impeller shaft 4 on opposite sides of the suction inlet 2 with their inlets 5 opposed. The impeller 3, 3 discharge into pressure chambers 6, 6, which are connected together, and are also in connection with the discharge pipe. The impellers 3, 3 work in parallel and their disposition is such that the end thrust of the one is counterbalanced by the end thrust of the other. At opposite ends of the pump casing 1 are chambers 7, 7, which contain the inner

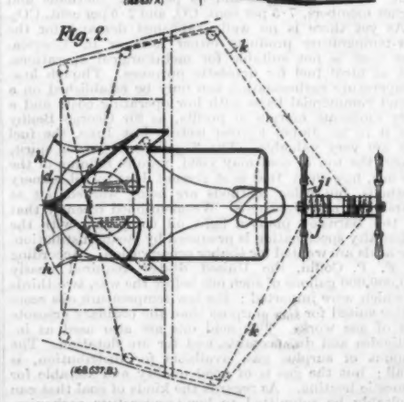


ends of the stuffing-boxes 8, 8 through which the impeller shaft 4 passes. The chambers 7, 7 are in connection with the pressure chambers 6, 6 through the clearance spaces at the peripheries of the impellers 3, 3, but are cut off from direct connection with the suction inlet 2 by the impellers 3, 3 and diaphragms 9, 9. The pressure in the chambers 7, 7 thus corresponds to the discharge head against which the pump is working, and as this pressure is at or above that of the atmosphere, there is no tendency for air to enter the pump casing through the stuffing-boxes, but for liquid to escape. (*Sealed.*)

### SHIPS AND NAUTICAL APPLIANCES.

**168,637. E. S. G. Rees, Wolverhampton. Manœuvring Ships.** (9 *Figs.*) May 25, 1920.—This invention relates to the propulsion and manœuvring of ships, aircraft and other craft driven by screw propellers wherein the fluid stream set in rearward motion by the propeller is confined within a fixed duct or tube which is open at each end and the direction of flow of the stream within the fixed tube and its issue therefrom is controlled by means of pivoted vanes or pallets at the rear end of the tube. Such a manœuvring apparatus enables the propeller to be driven continuously in one direction and the speed and direction of movement of the craft to be varied as required solely by manipulation of the manœuvring apparatus. The invention seeks to increase the efficiency of such manœuvring apparatus by improvements in the construction of the pivoted pallets and the means for operating them. In the improved construction the pallets *d*, *d*, which are mounted on parallel posts, the axes of which preferably lie between the longitudinal axis of the duct and the walls of the same, are formed with abutting tips on their rear edges shaped to remain in contact over a considerable angular




range of movement when the pallets are swung together in the same sense with closed rearward edges for sternward manœuvring. The sector arms *h*, by means of which the pallets are operated, are actuated by means of drums *j*, each having its own steering wheel *j*1, and flexible cords *k* which wind around the respective drums and are led around suitable guides and connected with the inner ends of the sector arms. The drums *j* are normally coupled by means of a clutch, which may be of the ordinary dog type, so that both pallets are actuated simultaneously by rotation of either steering wheel *j*1, but the drums can be declutched one from the other against the action of a return spring by outward axial movement of one of them, in which case the two steering wheels are separately usable for turning the pallets in either direction. Thus, the extent of the separation of the rear tips of the pallets which is required, is effected by the separate operation of one or both of the steering wheels and any subsequent joint movement of the pallets in the same sense for steering purposes is effected by the steering wheels in their clutched position. (*Sealed.*)